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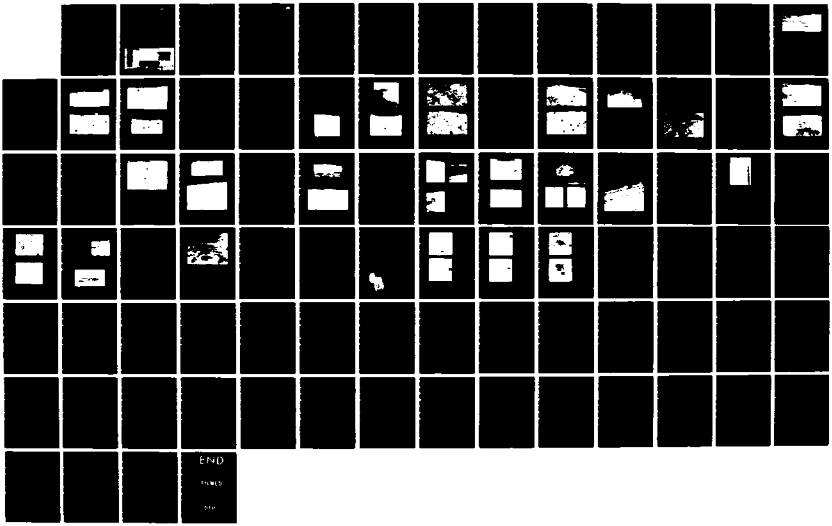

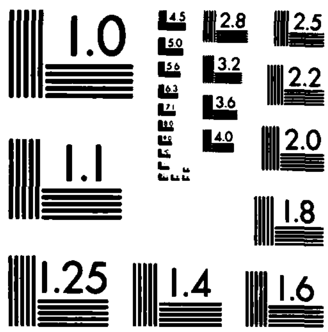


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# CRREL REPORT 85-11

AD-A158 724

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

# Reconnaissance observations of long-term natural vegetation recovery in the Cape Thompson region, Alaska, and additions to the checklist of flora

*For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380,* Metric Practice Guide, *published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

*Cover: Ogotoruk Creek valley in September 1961.*

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June 1985

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K.R. Everett, B.M. Murray, D.F. Murray,
A.W. Johnson, A.E. Linkins and P.J. Webber



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The diversity of disturbance types, landforms, vegetation and soils, together with the large, well-documented flora, makes Cape Thompson an ideal site to study long-term (20-year) environmental adjustments after impact. Man-caused disturbances there between 1958 and 1962 fall into three categories: runways, excavations and off-road vehicle trails. In addition, natural disturbance by frost action creates scars.

Reestablished vegetation after 20 years consisted of species found in adjacent undisturbed landscapes. Vegetation on excavations and cut-and-fill surfaces consisted of 3-5% vascular plants, of which *Deschampsia cespitosa* and *Sagina nivalis* are the

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most important (in terms of cover and frequency) of the 33 species identified. Cryptogams generally made up less than 1% of the vegetation, with lichens showing the least reestablishment.

Vehicle trails crossing both alkaline and acidic fell-fields are still visible. *Dryas octopetala*, dominant in the adjacent undisturbed tundra, has not been effective in either recolonizing the track areas or extending into the trail from either the center or sides. *Oxytropis nigrescens, Silene acaulis* and *Carex bigelowii* are the chief vascular colonizers. Cryptogams, especially lichens, have not generally been successful (less than 1% cover on the tracks) except in certain microsites and areas of bare soil where mosses make up 20-70% of the vegetation cover. On trails crossing *Dryas*-dominated solifluction slopes where hydraulic erosion has not been severe, plant colonization is 50% or more, and *Arctagrostis latifolia* is the dominant vascular plant; lichens constitute 10% and mosses 20% of the trail cover. Where hydraulic erosion has been severe (up to 2 m on solifluction slopes), little reestablishment of vegetation has taken place. Unless the soils were severely compressed or thaw subsidence occurred, trails in sedge tussock tundra were difficult to locate and consisted of wet meadow vegetation with a 95% cover of mosses as an understory. Thaw subsidence was commonly associated with trails crossing wet meadows or heath-tussock tundra. These trails, essentially barren when abandoned, now consist of rank stands of *Carex aquatilis* with variable amounts of *Eriophorum angustifolium* often masking smaller, water-filled thermokarst pits. Mosses, which commonly make up 90% or more of the undisturbed understory, are absent.

The tundra at Ogotoruk Creek has shown considerable resiliency in terms of reestablishment of vegetation, especially in the moister sites where bank slumping and lateral migration of vegetation is effective. On the more-exposed, better-drained sites, as on frost scars, the continuing interplay between physical and biological forces has prevented directional or progressive plant succession.

## PREFACE

This report was prepared by K.R. Everett, Department of Agronomy and Institute of Polar Studies, Ohio State University, Columbus; B.M. Murray, Institute of Arctic Biology (IAB) and Museum, University of Alaska, Fairbanks; D.F. Murray, IAB and Museum; A.W. Johnson, San Diego State University; A.E. Linkins, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg; and P.J. Webber, Institute of Arctic and Alpine Research, University of Colorado, Boulder.

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## INTRODUCTION

Tundras north of the Brooks Range have undergone accelerated exploration and development, both cultural and industrial. With this has come the need for land use planning. That term implies not only matching the proper soil-vegetation-landform units to a particular use, but also developing contingency plans for ancillary impacts (e.g., small hydrocarbon spills) as well as plans for reclaiming disturbed areas such as trails, borrow pits, drill and storage pads and roads if it becomes necessary to abandon a site.

Over the last decade much research has been directed toward understanding the dynamics of tundra vegetation (Tieszen 1978, Batzli 1980, Brown et al. 1980, Miller et al., in press). During the same period significant strides were made in developing base maps for land use planning (Everett et al. 1978, Walker et al. 1980, 1982, Walker 1983) and studying landscape rehabilitation (Van Cleve 1972, Cook 1974, Everett 1980b). Less attention has been paid to unaided morphological and biological adjustments in disturbed tundra landscapes (Hok 1969, 1971, Lawson et al. 1978, Drushinina and Zharkova 1979, Matveyeva 1979, Reynolds 1981, Gartner 1982, Lawson 1982, Komárková 1983).

Intensive studies concerned with reclamation and restoration of tundra ecosystems disturbed in the course of economic development of the Alaskan Arctic have a history of little more than a decade. Attempts at reclamation or restoration that have been or are being made have proven costly to initiate and maintain. In many cases these attempts may have been quite unnecessary if scientists and engineers had understood the rates and courses of natural adjustments in thermally and/or mechanically disturbed tundra. To achieve this understanding there must be a perspective of time. Old (20–30 years), massive, human disturbances of tundra in Alaska are rare, and rarer still are those that have not undergone subsequent human disturbance. Those that have been studied commonly exhibit a single kind of disturbance on a single terrain type.

The Ogotoruk Creek valley contains a number of disturbance types, ranging from slight to severe, that originated some 20 years ago (1958–1962) on geomorphically and botanically diverse terrain that has been little disturbed since. In addition the region had been studied in great detail at the time of disturbance, studies in which several of the authors of this report participated. The reconnaissance report that follows is an attempt to record some of the more apparent environmental adjustments in the Ogotoruk Valley, and by so doing, to stimulate interest in detailed research on the natural course of ecosystem adjustment following human disturbance. The study also addresses the topic of natural stability within sedge tussock tundra, which can offer clues to the rate and direction of adjustments in human disturbances.

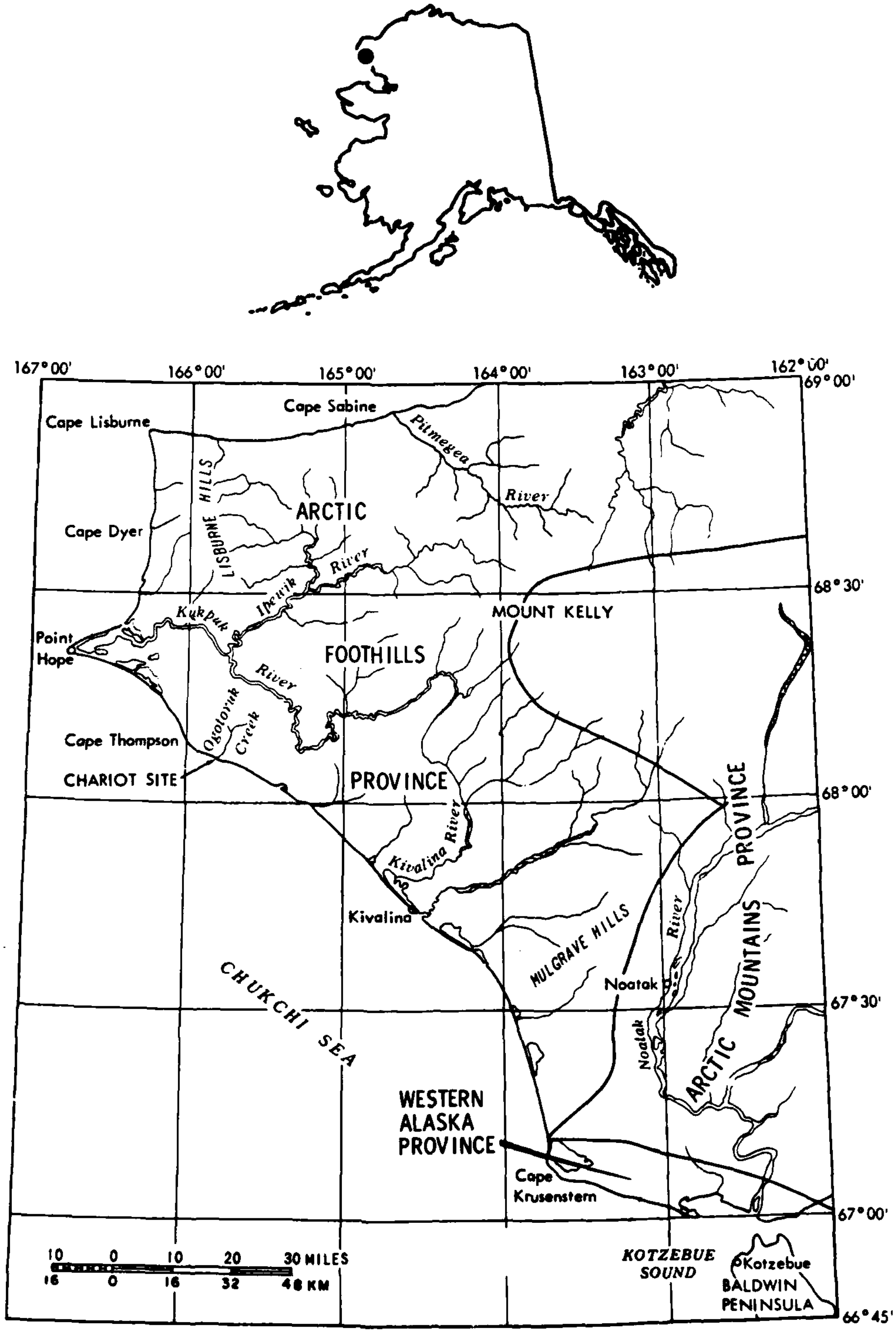



*Figure 1. Location of the Chariot site with respect to surrounding geography and physiographic provinces as defined by Wahrhaftig (1965). (After Chapman and Sable 1960.)*

# BACKGROUND

## History

In early 1958 the U.S. Atomic Energy Commission (AEC) authorized Project Chariot as part of the Plowshare Program to study and develop the peaceful uses of nuclear explosives. Chariot was to focus on the technical problems of nuclear excavation. The Ogotoruk Creek drainage basin (68° 06'N, 165°46'W), some 8.5 km southeast of Cape Thompson, was selected for study (Fig. 1), partly because of its remoteness and relative biological simplicity.

Because there had been no nuclear test experience in the Arctic and very little scientific knowledge of the environment as a whole existed, a bioenvironmental program was developed to permit adequate assessment of Project Chariot by establishing environmental baselines (Commission on Environmental Studies for Project Chariot, J.N. Wolfe, Chairman). The studies began in the summer of 1959 and continued through 1963. They covered the physical and biological components of the Ogotoruk basin, the physical and biological characteristics of the coast and adjacent Chukchi Sea, the cultural anthropology, and the ambient radioactivity and distribution of radionuclides. The results of this unique blend of science and engineering appeared as *Environment of the Cape Thompson Region, Alaska* (Wilimovsky and Wolfe 1966).

With the 1962 decision to defer further consideration of the proposed Chariot experiment, the bioenvironmental studies were suspended, although certain studies remained to be concluded in 1963. After 1963 the site was used sporadically for scientific studies, and beginning about 1968 limited logistic support was provided at the Chariot site by the Naval Arctic Research Laboratory. Although some off-road vehicle use has taken place in the Ogotoruk valley since 1963, it has been minor and has probably not been in the once heavily used areas of the Chariot study. The 136- and 234-m-long runways at the Chariot camp have seen only sporadic light-plane use; the 667-m runway across Ogotoruk Creek has probably been used more frequently.

## Physical geography

The physical characteristics of the Ogotoruk Creek basin and the general region of Cape Thompson are thoroughly discussed in Wilimovsky and Wolfe (1966). The following brief sketch serves only as a background against which to view some of the disturbances to be discussed. The major physiographic divisions of the Ogotoruk watershed are shown in Figure 2.

The asymmetric valley of Ogotoruk Creek trends north-northeast from the Chukchi Sea for some 11

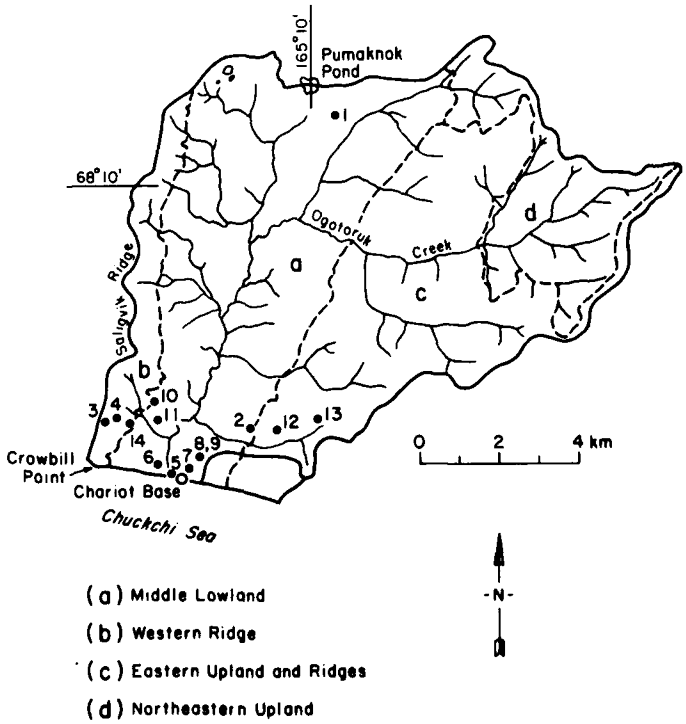



*Figure 2. Some sites studied for natural revegetation in the Ogotoruk Creek drainage. Numbered points refer to study sites: 1) Vehicle trail in wet meadow, 2) Vehicle trail on acidic fell-field, 3) Vehicle trail on alkaline fell-field, 4) Excavation in limestone talus, 5) 234-m-long gravel runway, 6) Vehicle trail in wet meadow, 7) 667-m-long gravel runway, 8) 220-m-long runway, 9) Frost scar tundra, 10) Excavation into shale, 11) Tussock tundra trail, 12) Excavation into greywacke/shale, 13) Excavation into greywacke/shale and 14) Vehicle trail on steep* Dryas *step. Frost scar sites are scattered throughout the drainage basin and are not shown.*

*Figure 3. View of the Ogotoruk Creek valley from the slope of Crowbill Hill (looking toward the southeast). The outcrops in the valley bottom are Mesozoic shales and mudstones. A segment of the multipass vehicle track can be seen crossing the broad, tussock-covered pediments on the far, west side of the valley and in the lower right corner. June 1962.*

km (Fig. 2). Ogotoruk Creek is a relatively broad, braided stream located near the axis of the valley, which ranges from 3 to 5 km in width. Primary tributary streams enter from the west. The bordering flat-topped ridges and valley walls on the east are composed of thrust-faulted Paleozoic limestone and dolomite and faulted Mesozoic argillite (Campbell 1966). On the west, Mesozoic shale, mudstone and greywacke underlie the terraced slopes. The valley bottom is filled with unconsolidated Tertiary and Quaternary gravel and silt through which Mesozoic shale and mudstone crop out (Fig. 3).

Within the watershed are large areas representative of both the wet sedge meadows of the Arctic Coastal Plain and the sedge tussock, frost scar tundra of the Northern Foothills.

Strong down-valley winds are common during all seasons, but especially during late summer and fall. Storms from the southeast and southwest contribute to a late summer and fall maximum of precipitation. Yearly totals of liquid precipitation may be between 20 and 25 cm (Allen and Weedfall 1966). Total winter snowfall probably does not exceed 55 cm during most years; snow covers the ground from October through June, although meltoff may begin as early as 1 May. The summers are cloudy (averaging 75% sky cover) and cool (the normal summer maximum is 11 °C and the minimum is 5 °C). Permafrost is continuous, and freezing temperatures extend to a depth of nearly 300 m (Lachenbruch et al. 1966). The maximum thaw is generally less than 50 cm in the wetter sites and up to a meter or more on the coarse-textured, southwest-facing slopes. Patterned ground is common, with nonsorted nets on the flat uplands; stripes, solifluction lobes and turf-banked terraces on southwest-facing slopes; and altiplanation terraces on the opposing slopes. Frost scars are common on the broad sedge-tussock-covered pediments of the west side of the valley and in the upper reaches of Ogotoruk Creek. These frost features may cover between 25% and 75% of a given area. Ice wedge polygons with surface expression are restricted to the valley bottom; both high- and low-centered forms occur.

## IMPACTS AND RECOVERY

Each of the major disturbance types was visited between 4 and 12 August 1980. The disturbances were of three main types: runway construction, excavations and off-road vehicle trails. General

assessments of the physical and biological (principally botanical) adjustments of the disturbed sites were made with reference to undisturbed areas. In addition 14 permanently marked linear transects were established. Abbreviated soil chemical and macrobiological analyses were made at intervals along these, as well as estimates of vegetation composition and cover. These analyses were made to document differences, if any, between disturbed and undisturbed areas and to serve as points of departure for future detailed studies. These data constitute the basis for much of the discussion that follows.

**Runways**

Four runways were built in support of the Chariot project between 1958 and 1959 (Fig. 2). The Chariot base camp is adjacent to two gravel runways, one extending 234 m northwest-southeast (study site 5, Fig. 2) and a second 136 m nearly due north (not studied). Runways were constructed mostly by smoothing elevated gravel beach deposits and building up the tundra surface with excavated gravel or by redistributing near-surface bedrock materials (Fig. 4). Like the camp, the runways have seen sporadic use since 1963, mostly by light, single-engine aircraft. East of Ogotoruk Creek are two runways: one is a 667-m-long cut-and-fill gravel surface trending northwest-southeast, and the other (site 8) is cut in mudstone and extends approximately 220 m nearly due north. The shorter of these runways is the oldest of the four and was used only until the longer one was completed in 1959. The long runway (site 7) was designed to accommodate larger, twin-engine aircraft (Fig. 5) and is still used commonly by light, single-engine STOL aircraft, which use relatively little of the surface (Fig. 5b).

Runway surface materials are naturally low in fines (i.e. silts and clays) and quickly develop a lag surface, especially when not used or regraded. The lag surface consists of a veneer of gravel fragments one to two fragments deep and generally less than 32 mm in diameter. Fines smaller than 2 $\mu$m are absent in the lag surface. In the 5 cm below the base of the lag, fines are present but compose less than 10% of the total fraction larger than 2 $\mu$m [this appears to be true elsewhere of road surfaces made of river gravel (Everett 1980a)].

The runway surface in August 1980 was uneven, with subsidence troughs that were up to 50 cm deep and 1 m wide. These troughs probably reflect ice wedges that have melted out beneath the gravel. The troughs are shallow, probably because the ice wedges were narrow and shallow, since bedrock is close to the surface. Polygonal crack patterns on the order of 1 m in diameter are visible on the runway surface but lack relief contrast. However, fine shale fragments are sorted and concentrated in the cracks, one to three fragments deep.

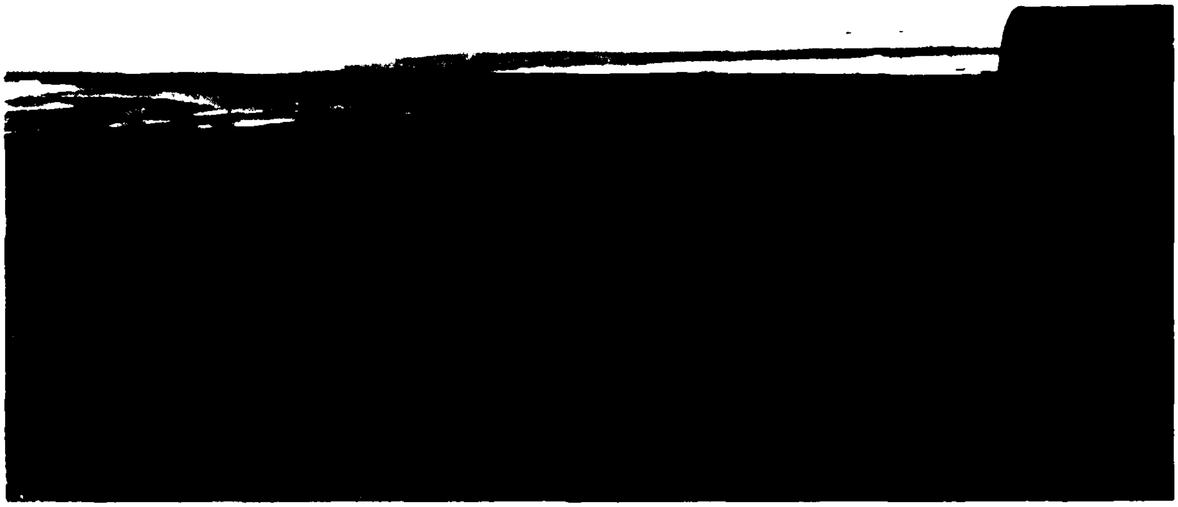
The grass *Deschampsia cespitosa* is the most common vascular plant colonizing the runways (Fig. 4b and 5b). Although at a distance it may present a rather continuous aspect, continuous stands greater than 0.25 m$^2$ are uncommon. At site 5 *Poa glauca, P. pseudoabbreviata* and *Festuca brachyphylla* are also primary species. At site 7 *Sagina nivalis* is a primary species along with *D. cespitosa*. Tables 1 and 2 list the primary and secondary vascular species at the two runway sites. *Arctagrostis latifolia* is conspicuous along the runway margins because these areas are not only somewhat moister than the landing area but also better drained and probably warmer than the surrounding tundra. *Salix alaxensis* is the only recolonizing willow on site 7 (Fig. 5a). At site 5 *S. glauca* and *S. ovalifolia* were found as secondary species. *Salix pulchra* is a secondary species on both runways and does not occupy significant areas.

Cryptogams occupy less than 1% of the runway surfaces. The primary mosses are *Ceratodon purpureus* (a weedy taxon) and members of the family Polytrichaceae (*Pogonatum dentatum, P. urnigerum* and *Polytrichum hyperboreum*). Isolated patches of *Bryoerythrophyllum recurvirostrum, Bryum* sp., *B. argenteum* and *Tortula mucronifolia* were also found. *Funaria hygrometrica* was noted at site 7. Among the few lichens seen were *Asahinea chrysantha, Cetraria cucullata, Lobaria linita, Stereocaulon* sp. and *Thamnolia* sp.

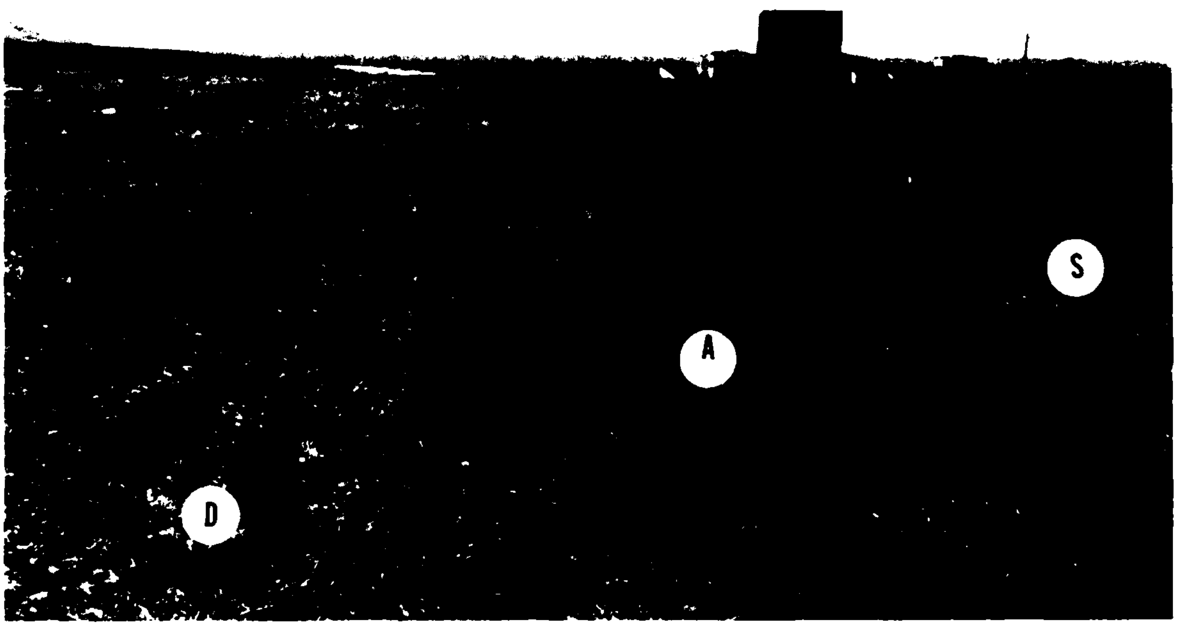
Of the 33 taxa recorded from the two runways (Tables 1 and 2), 48% were shared. Site 5 had the richer flora in both primary and secondary colonizers, probably because the adjacent tundra has a similar substrate.

The pioneering grasses, mustards and mosses that are found on the runways all originate from propagules carried to the site from the adjacent undisturbed tundra, where these plants are a very minor component of the vegetation, or they originate from plants on naturally unstable sites such as stream bottoms, beaches or frost scars.

On the runways there is very little rooting medium available except for interruptions in the lag surface where fines are exposed. Most vascular plant propagules arrive in August after the surface has dried, and therefore meet an environment unfavorable for germination—at least without overwintering. Many of the natural invaders of river



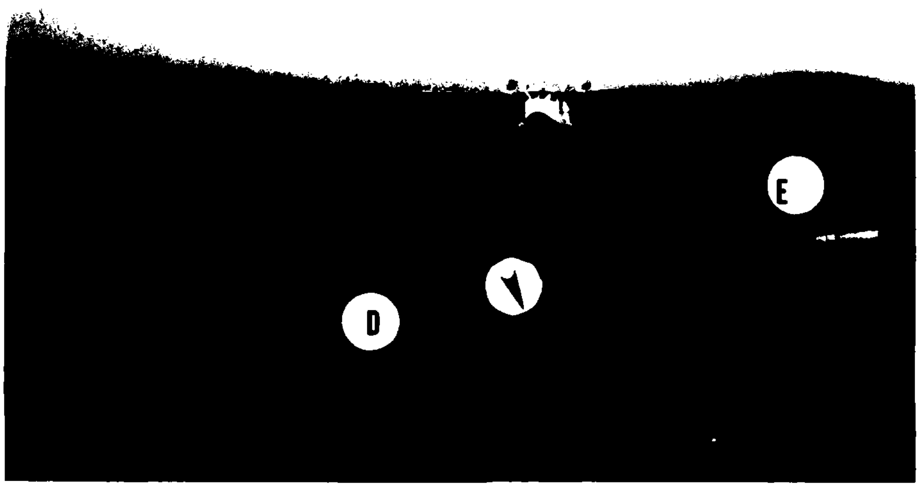
*a. The southeast end, taken in June 1960.*




*b. A more extensive view, taken in August 1980.* Deschampsia cespitosa *(D) is the principal plant on the graded surface.* Arctagrostis latifolia *(A) grows on disturbed margins. The willows (S) in the undisturbed area are* Salix pulchra *and* S. ovalifolia.

*Figure 4. Views looking southeast along the 230-m camp runway (site 5).*

*a. View along the line of transect. The willows in the undisturbed foreground are* Salix pulchra *and* S. glauca. *An individual of* Salix alaxensis *is marked by the arrow.*




*b. View along the runway toward the northwest. Note the clumps of* Deschampsia cespitosa *(D) and the scattered individuals of* Arctagrostis latifolia *(arrow).* Eriophorum scheuchzeri *(E) grows on the upslope ponded areas (right margin). August 1980.*

*Figure 5. Views of the 667-m runway (site 7).*

**Table 1. Species list for runway at Chariot camp (site 5).**

| *Primary species* | *Secondary species* | *Trace* |
|---|---|---|
| *Deschampsia cespitosa* | *Antennaria friesiana* | *Cochlearia officinalis* s.l. |
| *Poa glauca* | *Arctagrostis latifolia* | *Salix alaxensis* |
| *P. pseudoabbreviata* | *Artemisia arctica* | *S. pulchra* |
| *Festuca brachyphylla* | *A. glomerata* | |
| | *A. tilesii* | |
| | *Carex microchaeta* | |
| | *Castilleja caudata* | |
| | *Cerastium beeringianum* | |
| | *Douglasia ochotensis* | |
| | *Draba palanderiana* | |
| | *Epilobium latifolium* | |
| | *Festuca rubra* | |
| | *Leymus mollis* | |
| | *Luzula confusa* | |
| | *L. kjellmaniana* | |
| | *Minuartia arctica* | |
| | *M. elegans* | |
| | *M. macrocarpa* | |
| | *Oxytropis nigrescens* s.l. | |
| | *Poa lanata* | |
| | *Potentilla hyparctica* | |
| | *Puccinellia vaginata* | |
| | *Sagina nivalis* | |
| | *Salix glauca* | |
| | *Trisetum spicatum* | |

**Table 2. Species list for runway across Ogotoruk Creek (site 7).**

| *Primary species* | *Secondary species* |
|---|---|
| *Deschampsia cespitosa* | *Antennaria friesiana* |
| *Sagina nivalis* | *Arctagrostis latifolia* |
| | *Artemisia arctica* |
| | *A. tilesii* |
| | *Cochlearia officinalis* s.l. |
| | *Descurainia sophioides* |
| | *Epilobium latifolium* |
| | *Festuca brachyphylla* |
| | *Koenigia islandica* |
| | *Minuartia arctica* |
| | *M. macrocarpa* |
| | *Petasites frigidus* |
| | *Poa lanata* |
| | *P. pseudoabbreviata* |
| | *Potentilla hookeriana* |
| | *Puccinellia vaginata* |
| | *Salix alaxensis* |
| | *Saxifraga bronchialis* |
| | *Silene acaulis* |
| | *Trisetum spicatum* |

bar sites, a number of which are nitrogen fixers, are not present on the runway surface. This is somewhat contradictory to the finding of Yurtsev and Korobkov (1979) on the Chukchi Peninsula.

Those plants that germinate do so in an environment subject to surface winds that are stronger than in the surrounding tundra and that carry abrasives such as fine mineral materials or snow. The rooting media (below the lag gravel surface) range widely in nutrients. Cation exchange capacities are very low (less than 2 meq/100 g), which reflects the small amounts of organic clay-size materials (Table 3). Although the exchange complex that is available may be saturated with bases (free carbonates are commonly present), it is subject to rapid depletion and there is probably a very slow replacement of critical bases such as potassium. The small quantities of organic matter provide few nutrients, especially nitrogen and phosphorous.

At Cape Thompson it is likely, but not proven, that as the plants mature, the meager supply of nutrients is depleted and the pioneers, whose nutrient demands are naturally low, are quickly nutrient stressed. This situation is abetted by the low soil moisture near the surface. Most plants probably do not survive for many seasons, although there is no documentation of this. However, indirect evidence from sites along the Dalton Highway

**Table 3. Chemical characteristics of the near-surface materials of Chariot camp runways (sites 5 and 7).**

| *Site* | *Distance* (m)* | *Depth (cm)* | *pH†* | *Total carbon (%)* | *Organic carbon (%)* | *Calcite (%)* | *Dolomite (%)* | *CEC*** |
|---|---|---|---|---|---|---|---|---|
| 7 | 2.5 | Surface | 7.6 | 0.87 | 0.77 | 0.2 | 0.6 | 0.8 |
| | 12.0 | 0–5 | 5.8 | — | 0.94 | — | — | — |
| | 46.0 | 0–5 | 5.5 | — | 3.21 | — | — | — |
| 5 | 16.0 | 0–5 | 7.7 | 0.94 | 0.80 | 0.2 | 1.0 | 1.2 |
| | 22.0 | 0–5 | 7.7 | 0.91 | 0.74 | 0.4 | 1.0 | 1.4 |

* Measured from end of transect line.

† 1:1 water:soil.

** CEC = cation exchange capacity (meq/100 g dry weight).

**Table 4. Comparison of soil enzyme activity and respiration rates between runways and adjacent undisturbed areas.**

| | *Phosphatase* | *Endocellulase* | *Exocellulase* | *Respiration* |
|---|---|---|---|---|
| **230-m camp runway** | | | | |
| Site 5 | 298.2 (52.5) | 1.8 (1.2) | 3.2 (1.2) | 1.0 (1.2) |
| Adjacent area | 1381.1 (43.9) | 14.6 (3.5) | 8.8 (2.3) | 25.2 (2.5) |
| **667-m main runway** | | | | |
| Site 7 | 123.3 (20.0) | 2.56 (0.1) | 1.4 (1.2) | 1.8 (0.2) |
| Adjacent area | 962.6 (43.7) | 27.9 (3.2) | 3.6 (1.9) | 18.7 (2.0) |

Phosphatase: μg PNP per hr per gm dry wt of soil

Endocellulase: units per hr per gm dry wt of soil

Exocellulase: mg glucose equivalent per hr per gm dry wt of soil

Respiration: μL $O_2$ per hr per gm dry wt of soil

Standard deviations are in parentheses.

suggest that this is the case (Johnson and Kubanis 1980, Kubanis and Johnson 1980, Kubanis 1982). The larger, more robust clumps of *Deschampsia cespitosa* (Fig. 4) may be located in moister microsites; because of their size, they may be more successful in trapping wind-blown fine mineral and organic particles, thus meeting their nutrient needs for longer periods and conserving moisture. Plant response to artificial nutrient addition to substrates similar to the Cape Thompson runways has been amply demonstrated (Chapin and Chapin 1980, Johnson 1981, Gartner 1982).

There is no indication at Cape Thompson that the larger clumps of *Deschampsia cespitosa* or cushions of *Cochlearia officinalis* s.l. act as substrates for other plants, particularly for willows. The establishment of willows has been very slow, probably because of the lack of suitable substrates for seed germination. The only willows that have become established appear to have spread vegetatively from the adjacent undisturbed tundra.

Soil extracellular enzyme activity and soil respiration rate are measures of organic matter decomposition and microbial activity. Soil enzyme activities and respiration rates are significantly higher ($P = 0.01$) in the gravelly soils adjacent to the runway than in the runway soils (Table 4). The higher activities in the adjacent soils show greater organic matter decomposition and potential nutrient cycling. They also suggest that the organic material in the control soils is different in composition from that in the runway soils, since the total soil organic matter in the sites is not too different. This supports the contention that more than just the total organic content is important when determining a soil's suitability for revegetation. Increased wind

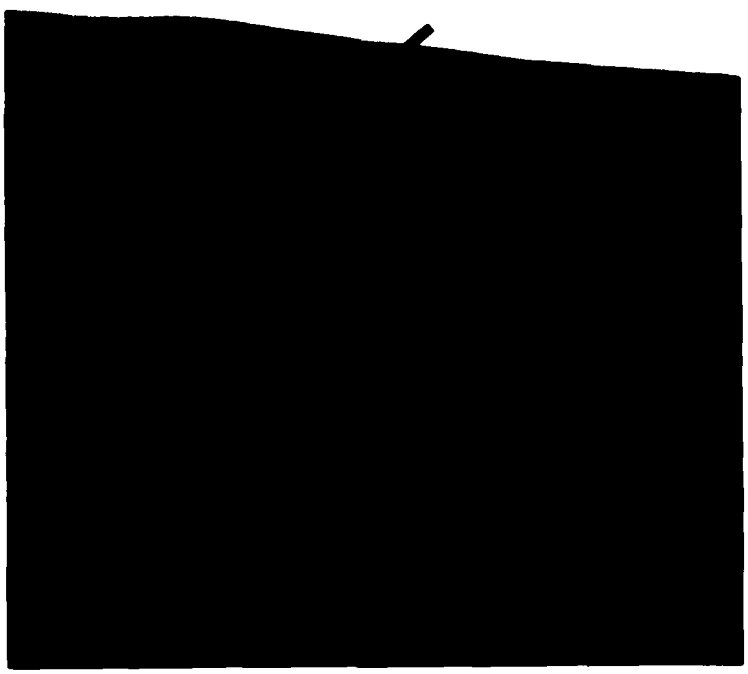
abrasion and water stress probably also contribute to the overall lack of revegetation on the runway sites.

The establishment of a cover of natural vegetation in the compacted gravel runways at Cape Thompson that approaches that of the undisturbed surfaces will take a long time, possibly hundreds of years, and will depend on the development of microsites, a general increase of site moisture, and the buildup of organic matter and release of nutrients through the slow process of mineral weathering. And in the end the vegetation on the runways may never duplicate the vegetation on the undisturbed surfaces.

**Excavations**

Six large, trenchlike excavations were made with a D-9 Caterpillar in the Ogotoruk drainage in August 1961 and June 1962. The excavations were made in order to map the structure of the active layer on slopes (Everett 1963, 1967). The trenches ranged in length from 18 m to about 300 m and were approximately 4.4 m wide. Three were excavated on the southeast-facing slope, one long one into limestone talus (site 4) and two shorter ones into Triassic shale (site 10; Fig. 2, 6 and 12). The three excavations on the northwest-facing side of the valley were cut into Jurassic-Cretaceous greywacke and shale (sites 12 and 13; Fig. 2). The excavations ranged in depth to well over 1 m. Although the depth commonly coincided with ice-cemented rock or talus (the frost table), in some cases it extended into the permafrost, which occasionally contained substantial amounts of ice (Fig. 7). After the excavations were completed, no attempt was made to restore the slope and no further use was made of them. The excavations and their associated debris piles represent one of the few known analogs of strip mining within the Foothills area of northern Alaska; another is the coal prospect at Knifeblade Ridge in the foothills west of Umiat (Fig. 19) (Everett 1980c).

After nearly 20 years only relatively minor changes were noted in the excavation through the limestone scree (Fig. 6). These are primarily slumps or spall from the cut banks. Only a few crustose lichens have become established. Because of the minor amount of bank collapse, sod clumps have



*a. The excavation (arrow) is clearly visible from across the valley.*

*Figure 6. Bulldozed excavation in a limestone talus slope as it appeared in August 1980.*

*b. The floor of the excavation appeared nearly unchanged in 1980.*

*Figure 6 (cont'd).*

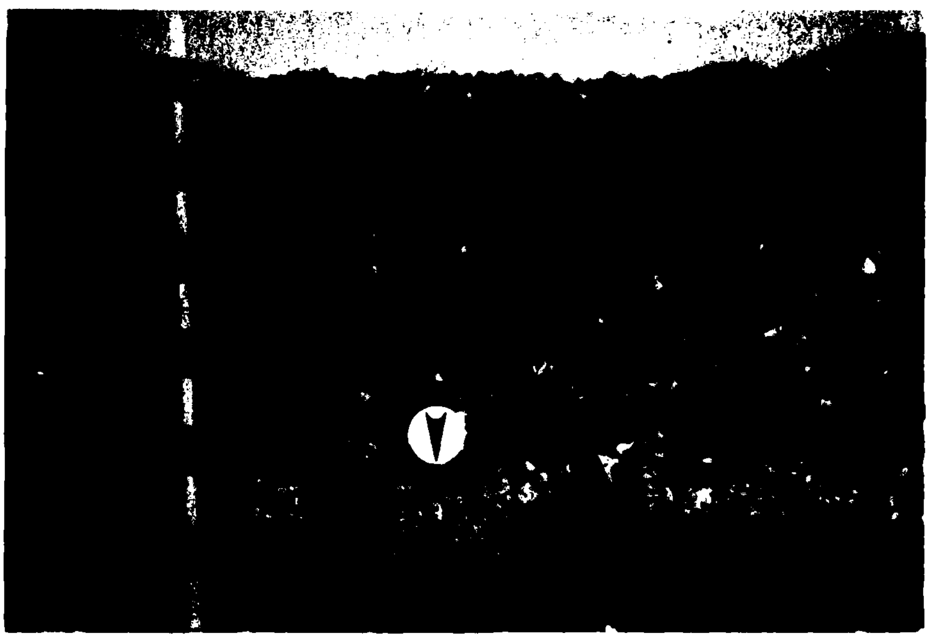
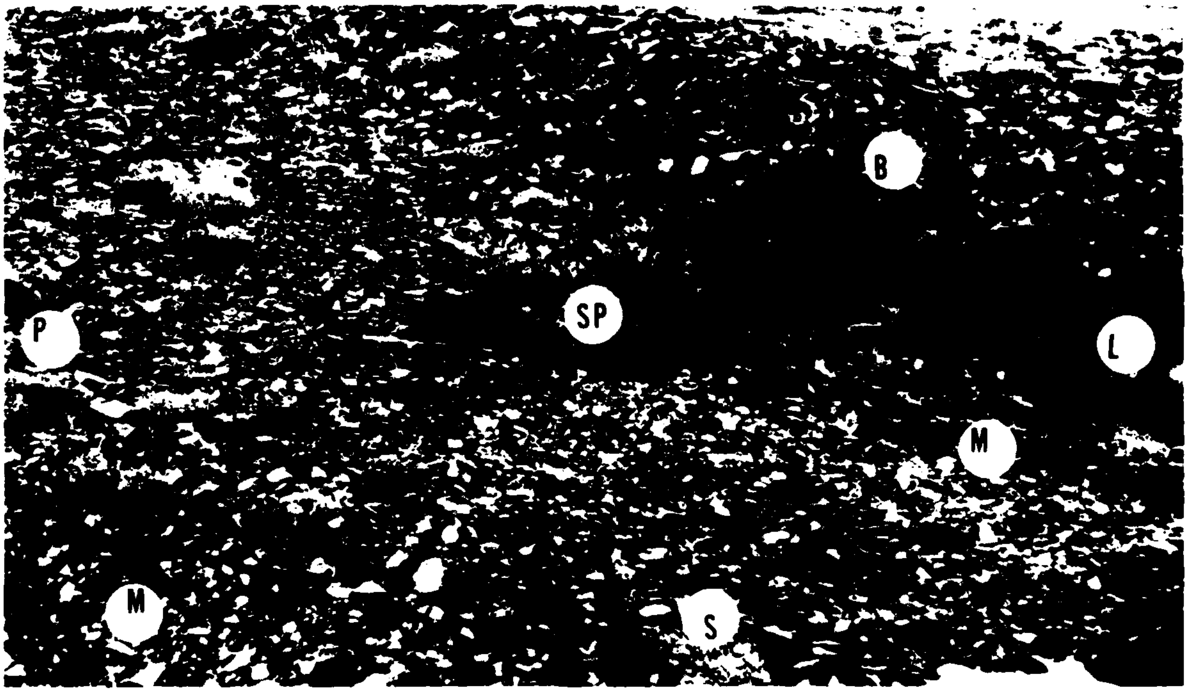


***Figure 7. Wall of the excavation into an acidic fell-field, Ogotoruk Creek (1961). The soil is an Arctic Brown (Pergelic Cryumbrept). The fractured bedrock surface is indicated by the arrow. These materials form the surfaces subject to natural revegetation. The increments on the rod are decimeters. Ice-bonded material occurred at base of the excavation.***


*a. S*—Stellaria longipes, *D*—Deschampsia cespitosa, *R*—Rumex acetosa, *B*—Betula nana.




b. S—Stellaria longipes, *SP*—Salix arctica, *B*—Betula nana, *L*—Lupinus arcticus, *M—moss, P*—Potentilla *sp*.

*Figure 8. South-facing debris ramp from excavation made in acidic fell-field. August 1980.*

not been important in creating a vegetation cover. The fine materials that do accumulate are washed down into the talus to the ice-bonded material and do not provide a rooting medium. Because of the southwest exposure it is unlikely that snow filling the ditch lasts more than a few days beyond that of the surrounding slope.

Excavations and debris piles on the shale–greywacke slope have somewhat more vegetation (Fig. 8 and 9). Both the debris piles and excavations provide a variety of microsites with a variety of moisture and temperature conditions to encourage or discourage the establishment of vegetation. This is in contrast to the homogeneity of the runways. In all cases a lag gravel surface forms on the floor of the excavation or the surface of the debris pile and is similar to that of the undisturbed sites (Fig. 9). However, the material in the top 5 cm on the undisturbed sites contains a much higher proportion of silt-size particles than material from similar depths in the disturbed surfaces; this is also true of the runway sites. Material from the top 5 cm in the undisturbed surface is also somewhat more acid than in the disturbed surfaces. However, organic carbon values for the two surfaces are not significantly different (Table 5) (in neither case was sampling done near vegetation).

Vascular plant cover on the disturbed excavation surfaces ranges between 3 and 5%, compared to 20% on the undisturbed fell-field. Grasses, especially *Deschampsia cespitosa,* form vigorous and apparently long-lived clumps in the moister microsites. *Stellaria longipes* is prominent as well, commonly forming coalescing mats. *Rumex acetosa, Lupinus arcticus, Silene acaulis* and *Artemisia* sp. are all present as widely scattered individuals. *Salix arctica* and *Betula nana* s.l. (Fig. 10) were found on several protected sites. On more-exposed, sloping surfaces (up to 22%) the vascular vegetation cover is less than 3% and composed mostly of *Diapensia lapponica, Potentilla* sp. and *Artemisia* sp. A few individuals of *Deschampsia cespitosa* are also present; this plant becomes more important on more-exposed and/or unstable sites (Fig. 9a).

The disturbed sites have few of the dominant species of the fell-field, which are *Salix phlebophylla, Oxytropis nigrescens* s.l., *Salix arctica, Dryas octopetala* and *Artemisia* sp. Taxa shared between the disturbed and undisturbed sites include *Lupinus arcticus*, which occurs both as individuals and scattered groups on undisturbed surfaces, *Artemisia* sp., *Deschampsia cespitosa* and *Salix arctica.*

**Table 5. Chemical characteristics of the near-surface (0–5 cm) of excavations and debris fill (site 9).**

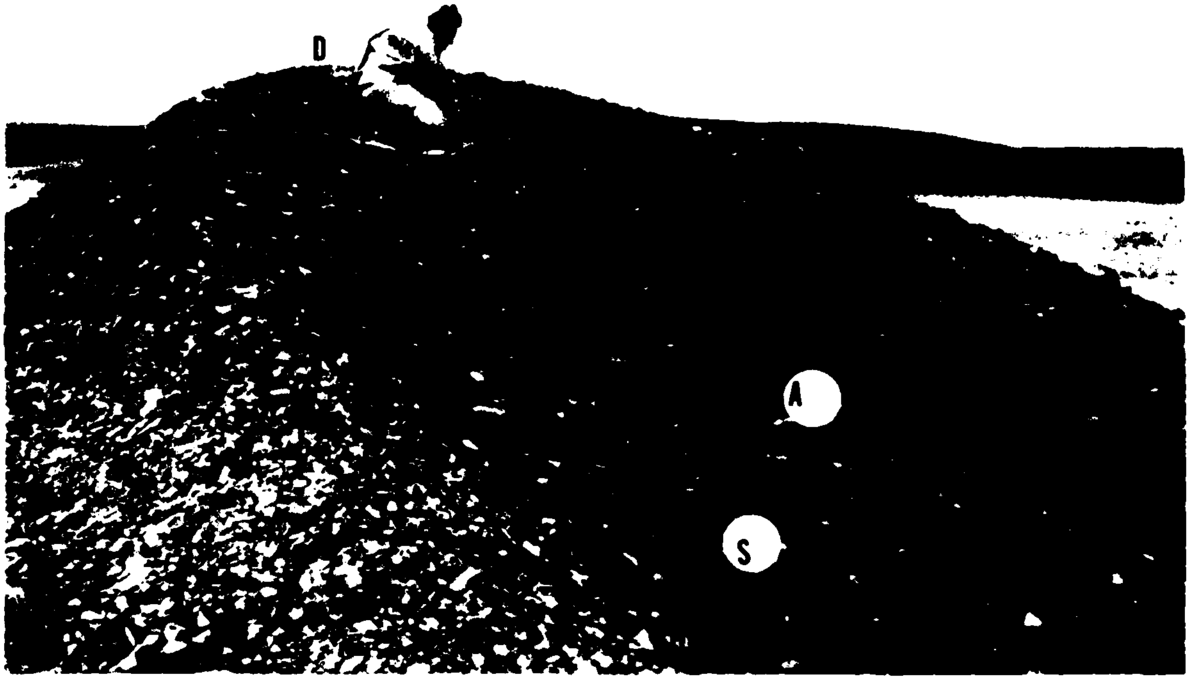
| | *pH** | *Organic carbon (%)* |
|---|---|---|
| Undisturbed | 5.3 | 1.11 |
| Undisturbed | 5.5 | — |
| Debris pile ramp | 6.0 | 0.97 |

* 1:1 water:soil.

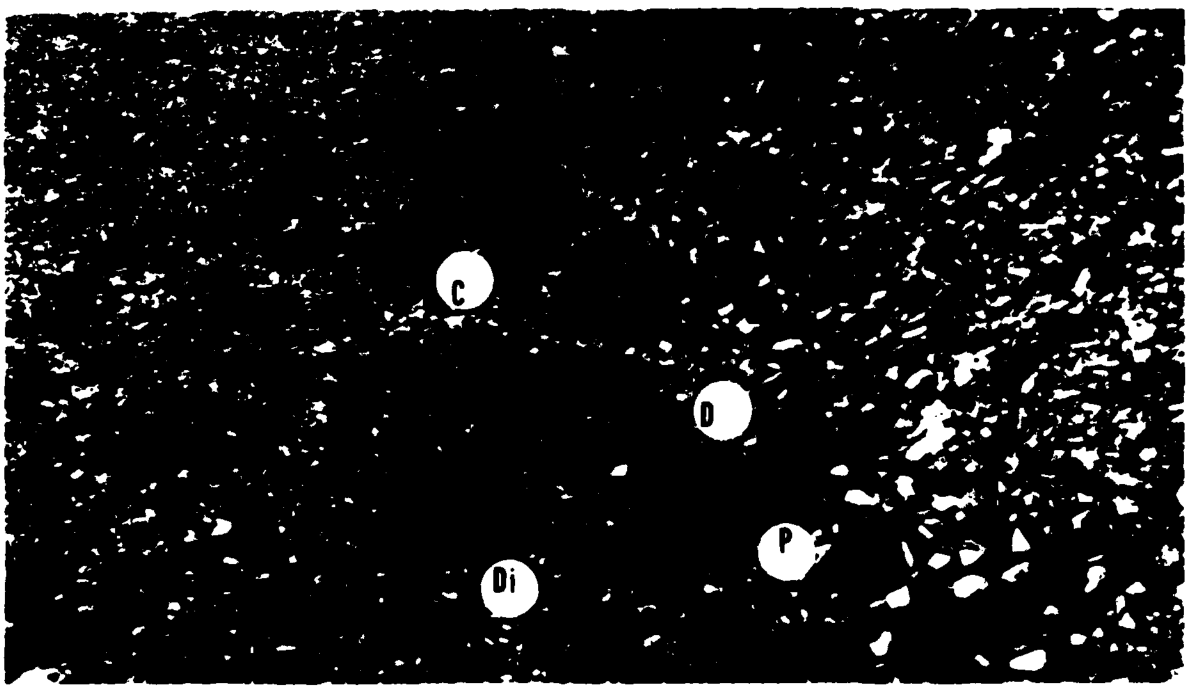
Ebersole and Webber (1983) found on 30-year-old bladed surfaces at Oumalik Test Well 1 that plants dominant in the undisturbed sites were poorly represented in the disturbed areas. These grasses and willows, especially *Salix alaxensis,* produce abundant seeds and are especially favored by warm surfaces and rapid nutrient turnover rates (mineralization). The high soil enzyme activity at the Ogotoruk excavations reflects a potentially rapid nutrient turnover rate. Ebersole and Webber concluded that as long as the nutrient regime remains enhanced by rapid decomposition, high soil temperature and availability of organic material, the present plant communities on the disturbed sites will persist, probably for hundreds of years.

The most significant and obvious difference in vegetation between the acidic and alkaline sites is in the lichen cover, which in acidic sites ranges between 50 and 70% cover on the undisturbed surface and near 0% on the disturbed. The primary lichen taxa in acidic fell-fields are *Ochrolechia* sp., *Cornicularia divergens* and *Asahinea chrysantha.* Secondary taxa among the lag gravel fragments are *Alectoria ochroleuca, Lobaria linita, Parmelia omphalodes, Stereocaulon* sp. and *Thamnolia* sp. Lichens on disturbed excavations consist of *Cetraria islandica, C. nivalis, Cladonia* sp., *Parmelia omphalodes, Sphaerophorus fragilis, Stereocaulon* sp. and *Thamnolia* sp., except on one stable slope of the excavation where patches of *Alectoria ochroleuca, Cornicularia divergens* and *Sphaerophorus globosus* were found. All these lichens are common in acidic fell-fields.

Mosses are unimportant in acidic fell-fields, and those that occur there were also found in the excavated area among rock fragments. Chief among the mosses in undisturbed sites are members of the family Polytrichaceae (*Pogonatum dentatum, P. urnigerum, Polytrichum hyperboreum, P. pilifer-*




*a. S*—Stellaria longipes, *A*—Artemisia *sp., D*—Deschampsia cespitosa.




*b. Vegetation on the adjacent undisturbed fell-field surface: D*—Dryas octopetala, *Di*—Diapensia lapponica, *C—Cryptogams, mostly lichens, P*—Poa *sp.*

*Figure 9. Ramp of excavated material. The slope on the right is 22%; the slope on the left is 56%. August 1980.*

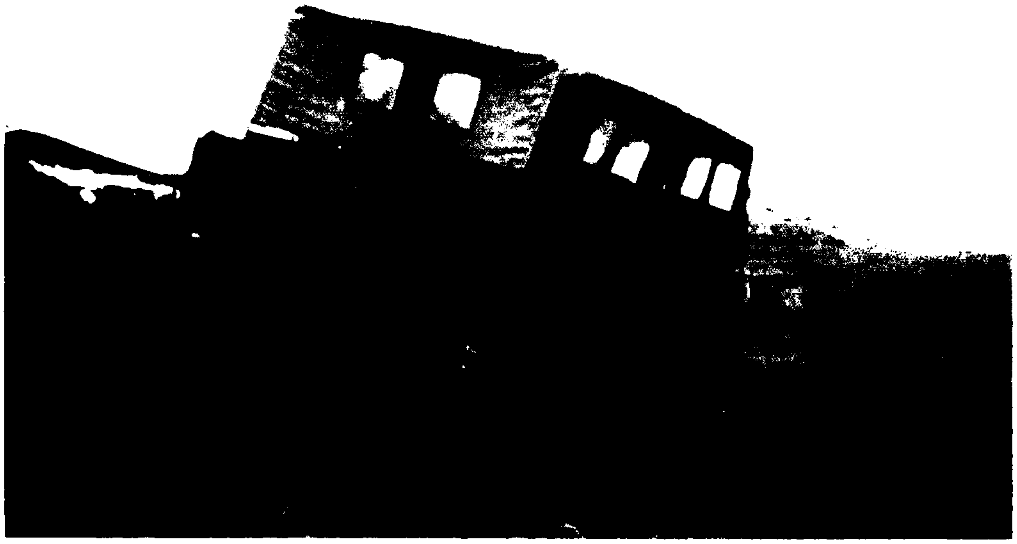


*Figure 10. M-29 personnel carrier (Weasel). These were the primary offroad vehicles used during Project Chariot.*

**Table 6. Soil enzyme activity and respiration rates from excavations in greywacke–shale (site 9) and limestone talus (site 11).**

| | *Phosphatase* | *Endocellulase* | *Exocellulase* | *Respiration* |
|---|---|---|---|---|
| **Greywacke-shale (pH 5.0)** | | | | |
| Site 9 | | | | |
| Unvegetated | 270.0 (13.3) | 0.0 | 6.8 (0.4) | 0.5 (0.1) |
| *Salix** | 510.2 (15.6) | 1.9 (0.1) | 10.6 (0.9) | 2.6 (0.5) |
| Adjacent area | | | | |
| Unvegetated | 228.9 (11.7) | 0.6 (0.1) | 9.0 (2.1) | 1.2 (0.2) |
| *Salix** | 493.3 (20.8) | 1.5 (0.2) | 12.4 (0.7) | 2.4 (0.4) |
| **Limestone talus (pH 7.4)** | | | | |
| Site 11 | | | | |
| Unvegetated | 256.2 (12.8) | 0.3 (0.1) | 3.1 (0.4) | 1.2 (0.5) |
| *Dryas** | 422.2 (42.2) | 2.5 (2.0) | 8.0 (0.9) | 3.3 (0.3) |
| Adjacent area | | | | |
| Unvegetated | 333.3 (24.0) | 0.8 (0.2) | 5.1 (0.8) | 2.5 (0.4) |
| *Dryas** | 515.5 (10.7) | 2.0 (0.3) | 10.8 (2.3) | 4.3 (0.2) |

Phosphatase: μg PNP per hr per gm dry wt of soil.

Endocellulase: units per hr per gm dry wt of soil.

Exocellulase: mg glucose equivalent per hr per gm dry wt of soil.

Respiration: μg $O_2$ per hr per gm dry wt of soil.

Standard deviations are in parentheses.

* Soils sampled immediately below plant; not exceeding 1 cm beyond island (canopy).

*um* and *Psilopilum cavifolium*). *Racomitrium lanuginosum* was also found. *Bryum* sp. and *B. argenteum* are secondary species. Moss patches occur occasionally on the disturbance; the heaviest cover (15–20%) is related to animal and bird perch areas, where the weedy mosses *Ceratodon purpureus* and *Bryum argenteum* are primary species. Elsewhere cover is less than 1%. On very steep, unstable disturbed slopes, vascular plants and cryptogams are all but absent after 20 years.

Unvegetated soil in excavations in greywacke-shale and limestone generally have lower extracellular soil enzyme activity and respiration rates than in adjacent soils ($P = 0.05$) (Table 6). These data indicate that even after 20 years the physically altered soils of the excavation sites still have reduced biological activity. This is probably due to the combination of the physical alteration of the rocky soil structure and the lack of accumulation of suitable organic material.

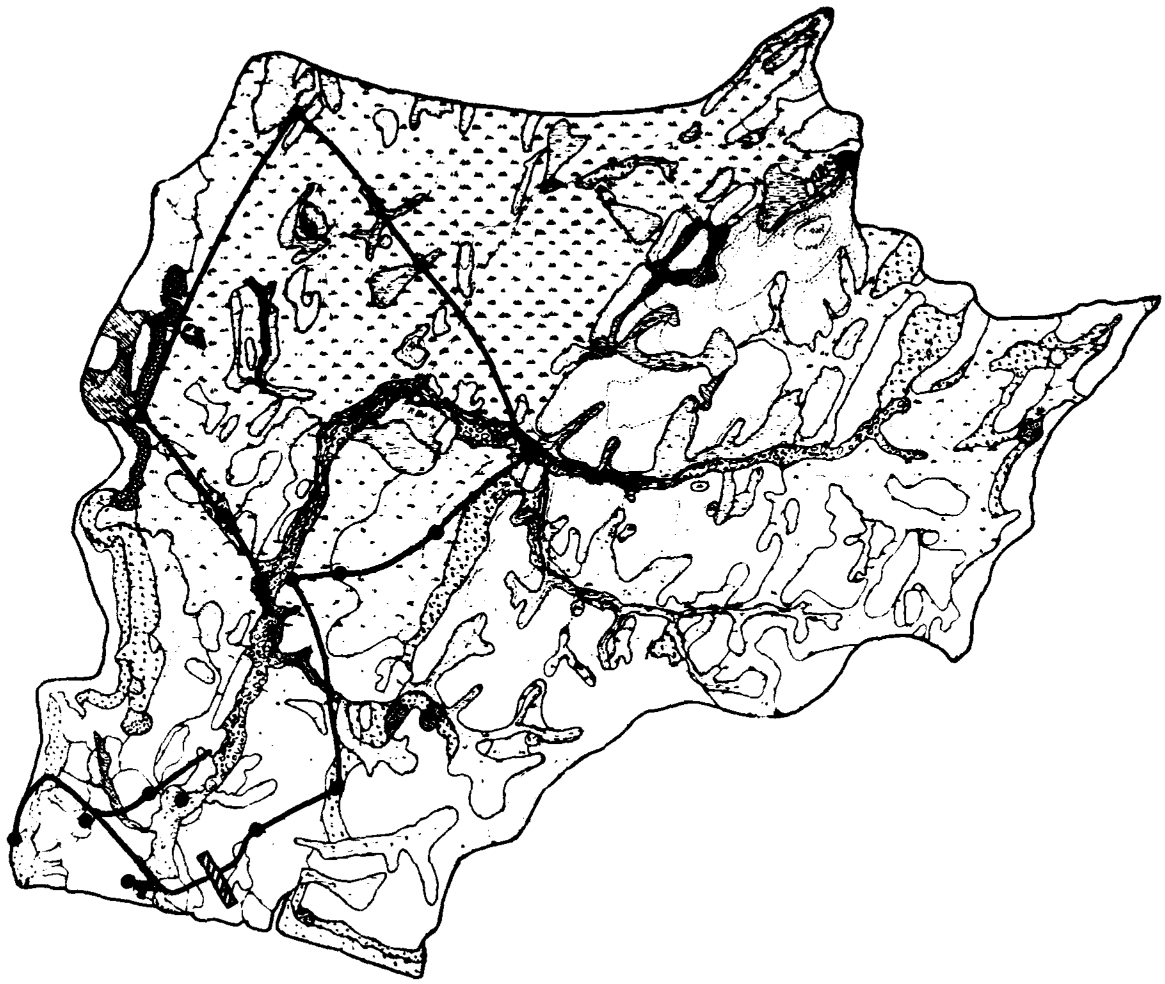
Soils from sites 9 and 11 that were sampled under a *Salix* or *Dryas* vegetation island have much higher enzyme activities and respiration rates than soils from nonvegetated areas (Table 6). In fact, there is little difference between the vegetated soils of the disturbed and undisturbed areas. This suggests that once a disturbed site has become revegetated, soil biological activities, if not soil characteristics, can become established at levels similar to ambient soils within at least 20 years.

Although permafrost was encountered in all excavations in 1960 and generally governed the depth of the excavation, significant ice bonding was observed only in the limestone scree (Everett 1963) and within the fracture planes in the fell-field excavation (Fig. 7). At the latter site there was sufficient ice accumulation that the bedrock collapsed upon melting. The original collapse features were pits up to 1 m deep that subsequently filled with water. In 1980 only one 0.5-m-deep water-filled pit remained. *Carex aquatilis* is scattered around the moist edge; this species is not present in the near surroundings.

**Off-road vehicle trails**

During the period of maximum activity at Cape Thompson, nine M-29 tracked personnel carriers (Weasels) (Fig. 10) and one Bombardier Snow Track were in nearly constant use from May through September (Fig. 11). Because repeated measurements at established sites were an integral part of several of the research programs, a circuit of service trails was inscribed on the tundra (Fig. 12). Although no records are available as to use of

*Figure 11. Service road to weather station. This trail also had early and late winter vehicle use (mostly Bombardier snow track). October 1961.*



**KEY TO VEGETATION TYPES**

- *Dryas* fell-field
- *Eriophorum-Carex* wet meadow
- *Eriophorum* tussock
- Wet-meadow tussock alternating streaks
- *Eriophorum-Carex* solifluction slope
- *Carex bigelowii* high-center polygon
- Ericaceous polygon
- Saline meadow
- *Dryas* step and stripe
- Snow-bed communities
- Gravel-bar and -bench communities
- Talus slope communities
- Ecotone communities

*Figure 12. Position of service roads with respect to major vegetation communities of Ogotoruk Creek.*

*a. Flagged stakes mark the ends of the study transect. Note the extensive lichen cover in the lower portion of the photo.*

*b. Note the general absence of vegetation in the track areas. The principal prostrate shrub is* Dryas octopetala.

*Figure 13. Service road crossing alkaline fell-field (Crowbill Hill). August 1980.*

these trails, 200–500 passes over the approximately 360 snow-free days of the project (1959–1962) is a reasonable estimate. The trail segments near camp were most heavily used, especially the segment between the Chariot base camp and Crowbill Hill. No attempts were made to stem subsidence or erosion; when a trail became too uncomfortable to drive, a new one was begun adjacent to it. The trail complex within the Ogotoruk drainage basin crossed most of the principal soil and vegetation units mapped in the watershed (Fig. 12) and provides ar unparalleled opportunity to study long-term recovery under a wide variety of vegetation, soil and topographic situations.

An unknown (but large) number of single-pass excursions using the M-29 were made to all parts of the watershed. The bed of Ogotoruk Creek or the existing Weather Bureau service trails served as the primary travel routes for such excursions. The extent to which these trails were used after 1963 is unknown, but it is believed to be light. During NARL administration the M-29 was used mostly for short forays in the creek bottom and as a supply carrier between the base camp and the large airstrip (site 7).

*Alkaline fell-field trails*

A heavily used trail crosses 0.6 km of *Dryas* fell-field at the crest of Saligvik Ridge (site 3, Fig. 2). No blading had been done prior to use. The undisturbed surface consists of mats of *Dryas octopetala* that range in size from a few square decimeters to one square meter. The mats extend 5–10 cm above the surface. The larger *Dryas* mats are weakly aligned northeast and southwest (Fig. 13b). Approximately 25% of the surface consists of frost-churned materials that form the centers of weakly expressed stone nets. Because of this instability, plant cover is variable. Smaller and less conspicuous cushion plants are *Oxytropis gorodkovii, O. bryophila, Minuartia arctica, Douglasia ochotensis* and *Silene acaulis*. The willow *Salix phlebophylla* is common and often associated with the *Dryas* mats. Completing the list of mat formers are *Salix arctica* and *Saxifraga eschscholtzii*. Scattered individuals of *Carex microchaeta, Hierochloe alpina, Luzula confusa, Kobresia myosuroides* and *Lupinus arcticus* also occur. Approximately 75% of the surface consists of weakly patterned lag gravel fragments that are 60–70% lichen covered.

The juxtaposition of acidic chert within calcareous rock has resulted in the presence of calcareous and acidic lichens on the same rock fragment, for example, *Rhizocarpon geographicum* on the resistant chert and *R. chioneum* on the limestone matrix. The ridge is dry and there are very few bryophytes present. The lichen cover in the undisturbed fell-field is 15–20% (excluding the ubiquitous saxicolous crustose species). The primary lichens are *Thamnolia* sp., *Evernia perfragilis* and *Ramalina almquistii*. Secondary species include *Alectoria nigricans, A. ochroleuca, Cetraria cucullata, C. nivalis, C. laevigata, Cornicularia divergens, Dactylina* sp., *Lecanora epibryon, Hypogymnia subobscura, Ochrolechia frigida*, including f. *thelephoroides, Parmelia omphalodes, P. separata* and *Physconia muscigena*. Mosses amount to 2% of the cover and include *Aloina brevirostris, Bryoerythrophyllum recurvirostrum, Distichium inclinatum, Hypnum procerrimum, Racomitrium lanuginosum, Rhytidium rugosum, Stegonia latifolia, Tortella fragilis* and *Tortula ruralis*.

Lichens are essentially absent in the Weasel tracks, except for a few crustose species on rock fragments. Moss cover is also low, about 1%, and consists of occasional patches of *Encalypta* sp., *Ditrichum flexicaule* and *Tortula ruralis* on moist soil. Here and elsewhere, *Encalypta* spp., which are generally found on fine bare soil, are more abundant in disturbed areas than in the undisturbed surface adjacent to the trail. The area between the tracks is similar to the undisturbed fell-field in plant cover and composition, but lichen cover is 10%, compared to 15–20% in the undisturbed areas.

*Dryas* and other mat formers persist in the undisturbed trail center (Fig. 13) and for the most part have not been disturbed. However, they have not extended much into the track areas. Recovery of the tracks has been minor and quite variable. This presumably reflects the microsite moisture supply. Chief among the colonizers are *Oxytropis nigrescens* s.l. and *Silene acaulis*.

The surface rock fragments are smaller in the track area than in the adjacent undisturbed area. Below the lag surface the amount of particles less than 2 $\mu$m is generally similar in the disturbed and undisturbed areas. The variability that does occur can be attributed to the presence of frost scars, which commonly have a higher proportion of silt and clay-size materials. The very limited amount of chemical data presented in Table 7 does not offer many clues as to the lack of recovery in the track areas. Soil enzyme activity and respiration in the tracks and the undisturbed fell-field are in the same pattern as recorded for runway surfaces and excavation sites (Table 8).

**Table 7. Chemical characteristics of the near-surface (0–5 cm) of trails across fell-field surfaces (sites 2 and 3).**

| Site | Distance* (m) | pH† | Total carbon (%) | Organic carbon (%) | Calcite (%) | Dolomite (%) | CEC** |
|---|---|---|---|---|---|---|---|
| 2 | 7 (undist.) | — | — | 4.60 | — | — | — |
| | 18 | — | — | 2.97 | — | — | — |
| 3 | 2 (undist.) | 7.1†† | — | 5.76 | — | — | — |
| | 6 | — | 9.21 | 5.75 | 14.9 | 12.8 | 28.8 |
| | 11 | — | 6.66 | 4.19 | 7.2 | 12.4 | 20.6 |
| | 17 (undist.) | — | 4.19 | 2.90 | 4.4 | 6.6 | 11.6 |

* Measured from the southwest end of transect stake line.
† 1:1 water:soil.
** CEC = cation exchange capacity (meq/100 g dry wt).
†† From Holowaychuk et al. (1966).

It is likely that the topographic exposure of the trail site (as with runway sites) is directly related to the lack of recovery. The degree of compaction of the surface may also play a role, but given the natural instability that results from frost heaving, it is difficult to understand why compaction has not been essentially eliminated in 20 years. The role of compaction in site recovery requires study. On a heavily used vehicle trail on sandy-textured alkaline substrate at Fish Creek, *Dryas integrifolia* is a successful recolonizer, covering an average area of 267 $cm^2$ per individual in 20 years.* Individuals of *Silene acaulis*, also a successful species, reached an average diameter of 33 $cm^2$ in the same period.

*Acidic fell-field trails*

A service trail was bladed shallowly into an acidic fell-field near the foot of the northwest-facing flank of the Ogotoruk valley (Fig. 2, 12 and 14). The surrounding undisturbed surface slopes gently, and the surface pattern consists of low terracettes and/or frost scars. The frost scars cover 25% or more of the surface.

The undisturbed fell-field vegetation cover is variable on the lower slopes but is generally more complete than in a similar fell-field on the alkaline hill crest. The lichen cover was estimated to be 70% (excluding crustose species on rock). There are many yellow lichens on and among the rocks, including *Asahinea chrysantha, Cetraria cucullata, C. nivalis, Cladonia amaurocraea, Lobaria linita* and *Rhizocarpon geographicum*. The typical brown-black lichens on the slate fragments are *Pseudephebe* sp. and *Cetraria hepatizon. Cetraria andrejevii* and *C. delisei* were found in late-lying snow areas and depressions. Mosses are uncommon, and only two or three taxa are shared with the summit fell-field.

Although the area is discussed under the heading of acidic fell-field, it is in most respects a transition or ecotone region, especially for the vascular plants. *Carex bigelowii* s.l. and *Salix pulchra* are the most characteristic taxa, especially on the lower parts of the slope. *Betula nana* s.l., *Dryas octopetala, Salix phlebophylla, Hierochloe alpina* and *Oxytropis nigrescens* s.l. are common in the area of the bladed trail (Fig. 14).

Blading of the trail removed most of the vascular plants and probably all of the cryptogams together with the upper 5 cm or so of the soil profile (a Pergelic Cryumbrept), leaving a surface with a greater amount of fine material than the surrounding area. This, together with a significant amount of organic materials, constituted a favorable seed bed (these soils are more acidic than those of the crest fell-field). The combination of these factors appears to have contributed to a higher moss cover in the road than in the undisturbed fell-field (15–20%, and up to 70% moss cover in areas where mineral soil is exposed). *Pogonatum dentatum* is the primary taxon; it was also recorded on the runway sites. Other mosses include *Bartramia ithyphylla, Ceratodon purpureus, Conostomum tetragonum, Dicranum* sp., *Encalypta brevipes, E. rhaptocarpa* and *Polytrichum piliferum*.

* K. Everett, unpublished data.

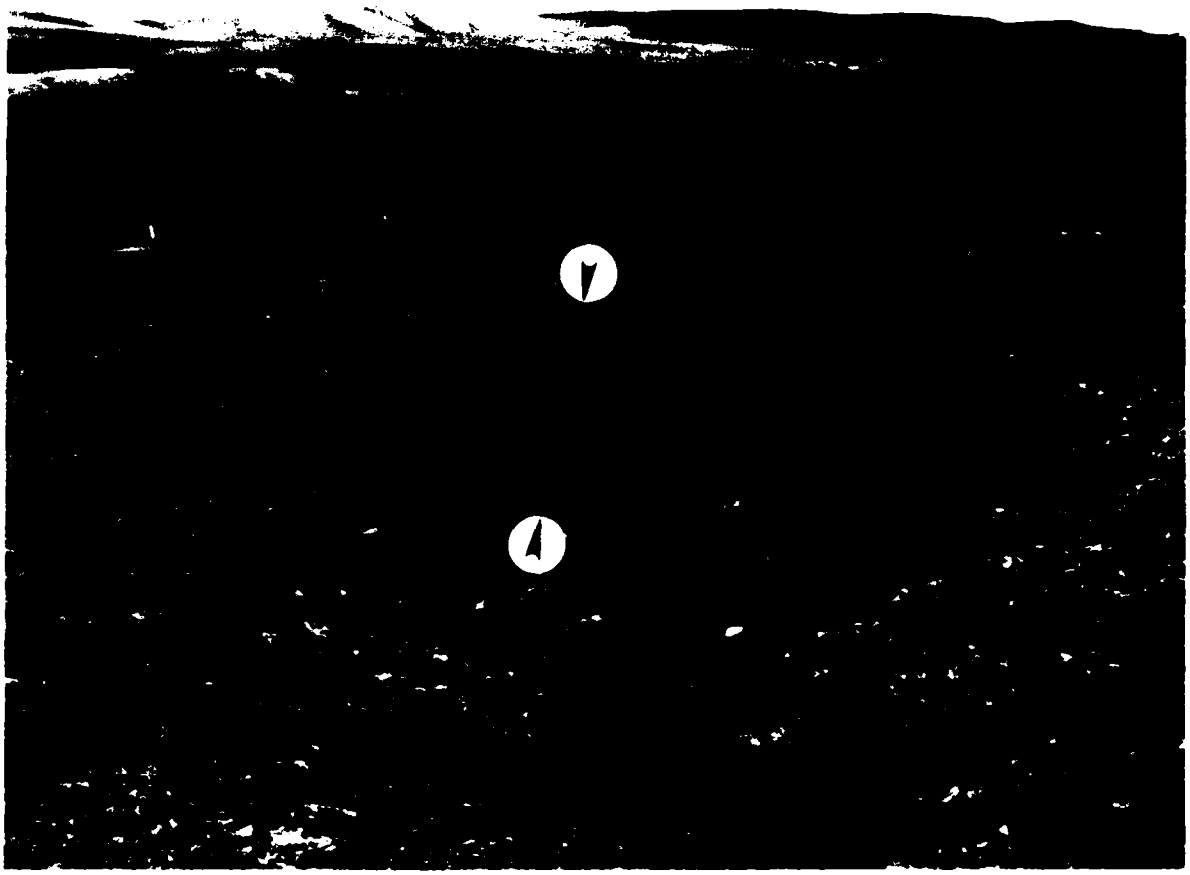


*Figure 14. Shallowly bladed trail across acidic ecotone and fell-field. Arrows show the edges of the trail. Note the extensive moss and lichen cover on the undisturbed area in the foreground. August 1980.*

Lichens are those typical of acidic fell-field, but are less abundant than in the undisturbed areas.

Vascular plants colonizing the bladed trail are *Carex bigelowii* s.l., *Oxytropis nigrescens* s.l., *Stellaria longipes, Dryas octopetala* and *Salix pulchra* (all taxa of the surrounding fell-field). It is likely that *S. pulchra* and possibly some of the *D. octopetala* resprouted from roots not destroyed by the light blading. These taxa appear to be most successful in the center of the trail not subject to later vehicle tracks. In general, recovery of this trail is the best of any dry site in the valley.

*Wet meadow trails*

More *Eriophorum-Carex* and *Eriophorum*-tussock meadow was affected by trails in the Ogotoruk Creek drainage than any other vegetation type (Fig. 12). Figure 15a shows a trail crossing *E. angustifolium-C. aquatilis* tundra near the northern boundary of the drainage basin. These trails were especially damaging to wetter areas, yet many such areas have shown a remarkable capacity for recovery, especially where the underlying permafrost was not ice rich.

The area near Pumaknok Pond (site 1, Fig. 2) is generally a heath tussock tundra. Ridges and hummocks are common on the undisturbed areas but absent from the trail area. The trail area is characterized by rank stands of *Carex aquatilis* with minor amounts of *Eriophorum angustifolium*, a species common in the undisturbed tundra. Mosses are abundant and have a cover value of 95% as an understory. The species are indicative of neutral to acidic, wet conditions and include as primary species *Drepanocladus* spp. and *Sphagnum* spp. Secondary species are *Aulacomium palustre, Oncophorus wahlenbergii* and *Polytrichum strictum*. Lichens are very rare in the trail. Ubiquitous lichens such as *Cetraria cucullata, C. islandica, C. laevigata, Cladonia* spp., *Peltigera*

*a. Trail as it appeared in September 1980. Note the numerous water-filled depressions.*

*b. Portion of the trail as it appeared in August 1980. The pipe and shovel in the distance mark the ends of one of three transects. The vegetation consists of* Carex aquatilis, Eriophorum angustifolium *and* Salix arctica *on raised areas (strangs).*

*Figure 15. Weasel trail crossing an area of wet meadow-tussock tundra south of Pumaknak Pond.*

**Table 8. Soil enzyme and respiration rates in several trail sites.**

| | *Phosphatase* | *Endocellulase* | *Exocellulase* | *Respiration* |
|---|---|---|---|---|
| **Alkaline fell-field (dry)** | | | | |
| Site 3 | | | | |
| Track (pH 7.5) | 159.9 (12.6) | 3.2 (1.0) | 6.2 (0.9) | 2.5 (0.6) |
| Adjacent area (pH 7.3) | 305.5 (23.3) | 7.5 (1.3) | 7.0 (0.7) | 3.9 (1.0) |
| **Wet meadow** | | | | |
| Site 6 | | | | |
| Track (pH 6.0) | 1677.7 (107.2) | 37.1 (3.2) | 144.5 (64.6) | 27.1 (5.0) |
| Adjacent area (pH 5.7) | 1899.9 (88.2) | 29.5 (3.1) | 65.6 (37.0) | 18.3 (3.0) |
| **Tussock, wet meadow** | | | | |
| Site 1 | | | | |
| Track (pH 5.4) | 441.0 (10.8) | 11.2 (3.0) | 64.3 (4.7) | 20.1 (1.3) |
| Adjacent area (pH 4.8) | 532.2 (18.4) | 6.1 (2.1) | 14.5 (1.0) | 8.7 (1.2) |

Phosphatase: $\mu$g PNP per hr per gm dry wt of soil.

Endocellulase: units per hr per gm dry wt of soil.

Exocellulase: mg glucose equivalent per hr per gm dry wt of soil.

Respiration: $\mu$L $O_2$ per hr per gm dry wt of soil.

Standard deviations are in parentheses.

*aphthosa* and *Sphaerophorus globosus* were seen on hummocks in undisturbed heath tussock vegetation (included in the *E. angustifolium–C. aquatilis* community). The hepatic *Anthelia juratzkana*, which is common on acidic frost scar surfaces, is found here.

Active layer thickness measured along three cross sections at site 1 in early August 1980 did not show significant differences between the trail site and the undisturbed tundra.

One of the more interesting and heavily used trails at Ogotoruk Creek is shown in Figure 16a as it appeared in early June 1960. This trail extends from the Chariot Camp air strip (site 6 and 14, Fig. 2) to the crest of Saligvik Ridge. The trail crosses four vegetation types, two soil complexes, and nearly the complete spectrum of slopes (Fig. 12). Except for a narrow area of mesic shrub tundra (containing *Salix* sp. and *Betula nana* s.l.) that reflects the somewhat better drained silts over ancient beach gravels, the first half of the trail crosses an *Eriophorum–Carex* wet meadow with well-developed ridges or strangs (Fig. 2 and 16b); in most respects it is similar to site 1. In the undisturbed wet meadow tundra, ridges form mesic sites 15–25 cm or more above their surroundings, with *Betula nana* s.l., *Salix pulchra, S. reticulata, S. ovalifolium, Ledum decumbens, Vaccinium uliginosum, V. vitis-idaea* and *Rubus chamaemorus* common on these ridges. *Dryas integrifolia* may also be found. Herbaceous species include *Aconitum delphinifolium, Corydalis pauciflora, Cardamine microphylla, Eutrema edwardsii, Saxifraga nelsoniana, S. hieracifolia, Polemonium acutiflorum* and *Valeriana capitata.*

Within the recovered track area, *Eriophorum angustifolium* and *Carex aquatilis* form dense stands that sometimes mask water-filled thermokarst pits. On slightly elevated microsites *Salix* sp. is found.

There was no significant difference in active layer thickness in August between the track area (ranging from 37 to 65 cm with a mean of 49 cm) and the control (ranging from 35 to 77 cm with a mean of 54 cm). Soil profiles, however, clearly reflect the disturbed nature of the active layer (Fig. 17). The OA and A horizons represent the churned organic and mineral materials of the trail. The upper 10 cm (OA horizon) are also characterized by a very high percentage of roots, in some cases as much as 75% of the volume.

Examination of soil enzymes and respiration in the trails crossing wet areas revealed that, unlike at the dry sites, only phosphatase activity was lower in the track then in adjacent areas. Cellulase activity and respiration rates were higher (Table 8). These changes, which accompany increased plant productivity, are thought to be due to increased

*a. As it appeared in June 1960.*

*b. As it appeared in August 1980. It crosses an* Eriophorum-Carex *wet meadow underlain by calcareous gray and dark gray soils (Pergelic and Histic Pergelic Cryaquepts). In the foreground some base soil, a frost scar, appears; the graminoids* Hierochloe alpina *and* Arctagrostis latifolia *dominate the naturally recolonized area.*

*Figure 16. Crowbill Hill road.*

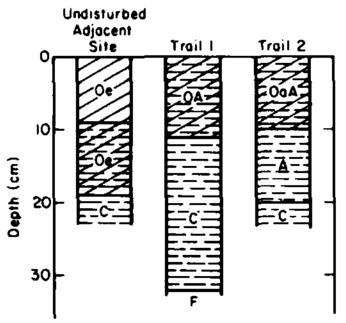



*Figure 17. Soil profiles across the* Eriophorum–Carex *tundra portion of Crowbill Hill trail. The water table is at the surface in the trail, and the upper soil horizons contain a very high percentage of* Carex *and* Eriophorum *roots, which impart a spongy character to the surface.*

water flow, which increases oxygenation and nutrient movement; the availability of inorganic phosphorous is increased, and conditions for more complete decomposition of plant structural material are improved. This phenomenon has been observed naturally in the water track tundra of the foothills (Everett 1980c)* and has been observed in other vehicle tracks.† Challinor and Gersper (1975) have documented significant changes in soil chemistry contributing to enhanced nutrient status in vehicle tracks at Barrow.

The near recovery of the surface elevation profile in some areas of the trail bears further study. This recovery may be due in part to the buildup of permanent ice at the base of the active layer; substantial clear ice was observed in a drill hole made in a track in 1979. If this can be substantiated, it represents a case of nearly complete recovery not only of vegetation but of topography as well. This is probably only possible in areas that lacked significant ground ice prior to the disturbance.

Toward Crowbill Hill the *Eriophorum-Carex* wet meadow becomes moderately sloped (Fig. 16b), and some subsidence was noted in the trail, which, like its lower, more poorly drained segment, has recovered. *Eriophorum angustifolium* and *C. aquatilis* are both rhizomatous propagators adapted to wet soils and have moved into the trail from the surrounding undisturbed tundra.

* Also personal communication with F.S. Chapin, III, University of Alaska.

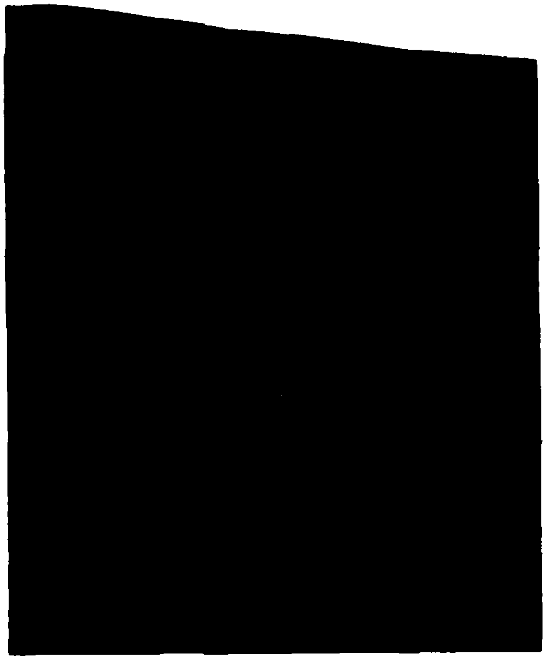
† Personal communication with G. Shaver, Marine Biological Station, Woods Hole, Massachusetts.

*Solifluction slope trails*

The Crowbill Hill trail ascends across a section of solifluction slope where the grade ranges between 12 and 18% (Fig. 18). Covering this section is a relatively thin veneer of organic-rich soil over coarse-grained colluvial deposits derived from both acidic (shale) and carbonate rocks. Hydraulic erosion of this part of the trail began early in its use and continues to the present (Fig. 18). The erosion, which extends to depths of 2 m, is most severe on the north (oblique downslope) side of the track. Where the trail is most deeply channeled, bedrock is exposed, and eroded colluvial materials have been spread out as fans and stripes where the slope breaks from 14–25% to 10% (Fig. 18). In the most severely eroded areas there is little or no recovery of vegetation. *Salix alaxensis* has established in a few areas. This willow is generally an effective pioneer on natural and man-made disturbances and especially favors alkaline soils, for example, debris fans in Atigun Canyon (Everett 1980c), the coal prospect at Knifeblade Ridge (Fig. 19) and an eroded mineral soil at West Oumalik (Ebersole, in prep.). *Equisetum arvense* and *Arctagrostis latifolia* have been effective in partially recolonizing the wetter, more stable areas of the debris aprons.

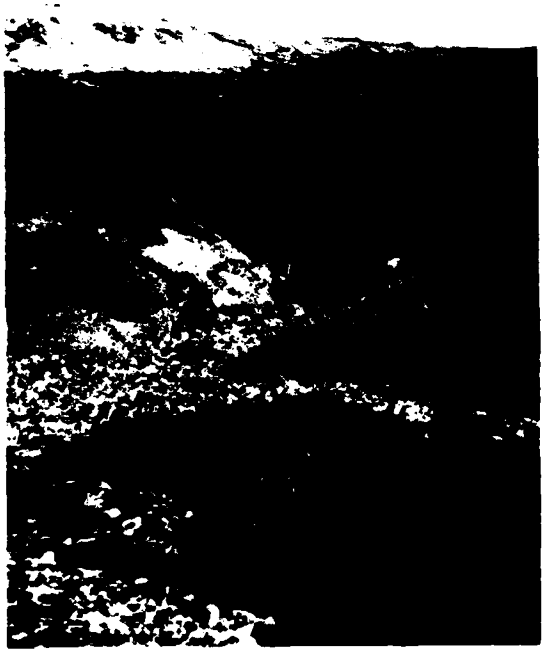
The undisturbed solifluction slope is a *Dryas* heath with 80–90% moss cover and 5–10% lichen cover, with lichens mainly on hummocks. The primary mosses are *Aulacomnium palustre, Drepanocladus uncinatus, Rhytidium rugosum* and *Tomentypnum nitens* (all common in moist calcareous *Dryas* tundras). Secondary taxa include *Dicranum* spp. (on hummocks), *Drepanocladus* sp., *Encalypta procera, Orthothecium chryseum* and *Tortella fragilis.* Lichens are found in areas of frost disturbance (*Bryoria nitidula, Cornicularia divergens, Lecanora epibryon* and *Thamnolia* sp.).

The undisturbed turf between the tracks in the driest area of the Weasel trail has a cover of about 10% lichens and 20% mosses. *Cetraria cucullata, C. islandica* and *Solorina* sp. are seen, as are such mosses as *Bryoerythrophyllum recurvirostrum, Bryum* sp., *Dicranum* sp., *Distichium inclinatum, Encalypta procera, Myurella julacea* and *Timmia* sp. on scraped areas. There is a thin moss cover consisting of *Bryobrittonia longipes, Encalypta alpina, Myurella julacea, Plagiobryum demissum, Rhytidium rugosum, Timmia* sp., *Thuidium abiet-*



*a. As they appeared in August 1980.*

*b. Service road as it appeared in August 1960 at the point of maximum hydraulic erosion.*



*c. Erosion on the service road in August 1978.* Salix alaxensis *appears on the eroded area in the center and left side of the photograph.* Equisetum arvense *and grasses occur on the debris apron.*

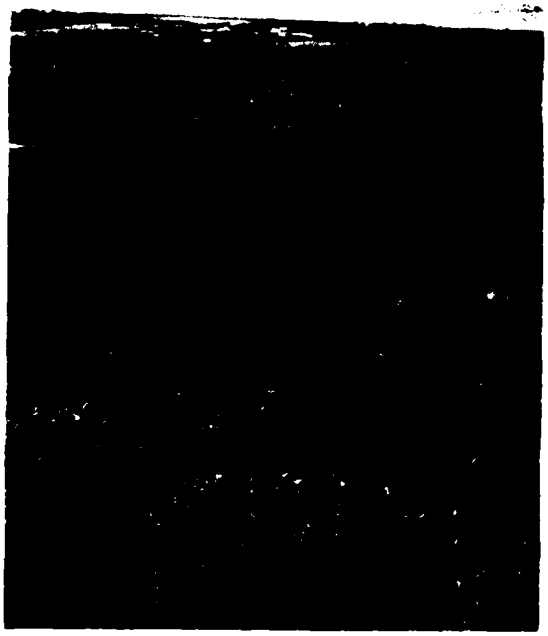
*Figure 18. Crowbill Hill excavation and service road.*

*a. The willows are* Salix alaxensis *and* Salix pulchra.

*b. The coal seam is exposed in the lower right. The cut was man-made.*

*Figure 19. Coal prospect just south of Knifeblade Ridge and down the valley from Knifeblade #1 test well. The site was disturbed about 1952. The soil is alkaline (pH 7.8–8.1). Originally the site was covered by sedge tussock tundra (pH 5.0–5.7).*

*a. As it appeared in August 1960.*



*b. Hydraulic erosion in step and stripe vegetation community in 1980 shows partial closure due to bank slump.*

*c. Recovery of the colluvial slope as it appeared in August 1980. The senesced grass is mostly* Arctagrostis latifolia. *Moss is an important understory plant.*

*Figure 20. Upper part of the Crowbill Hill service road.*

*inum* and *Trematodon brevicollis*, all reflecting the calcareous soil. In the track are mosses common to drainage areas (*Bryum cryophilum, Philonotis tomentella* and *Drepanocladus revolvens*) but essentially no lichens. Farther upslope, where bedrock is closer to the surface and hydraulic erosion is less effective, bank slump carrying vegetation from the surrounding undisturbed tundra has partially closed the erosion scar (Fig. 20b).

### Dryas *step and stripe trail*

Above the eroded section, the trail crosses a *Dryas* heath with turf-banked terraces (Fig. 2 and 20) and then rises steeply across an area of talus slope vegetation communities (*Dryas* stripes) before turning onto the crest of Crowbill Hill. Throughout this distance the soils are neutral to slightly alkaline, with profiles generally similar to the fell-field soils in Table 5. Where the pitch of the trail is less than about 20%, the undisturbed tundra is rich in plant species; Johnson et al. (1966) recorded more than 60 vascular species here. *Dryas octopetala* is dominant. Other important species are *Carex scirpoidea, C. bigelowii* s.l., *Salix arctica, S. rotundifolia, Astragalus alpinus, A. umbellatus, Oxytropis maydelliana, O. borealis, O. varians, Hedysarum alpinum, Polygonum bistorta, Phlox sibirica, Pedicularis capitata* and *P. oederi*. Lichens and bryophytes are relatively unimportant.

Along the steeper part of the trail (with a grade of 20–40%), apparently stable *Dryas* stripes alternate with boulder stripes with variable lichen cover (Fig. 21). In addition to *Dryas* the stripes contain most of the fell-field plants described earlier, as well as *Carex nardina, Arnica frigida, Artemisia borealis, A. furcata, Parnassia palustris,*

*Figure 21. Portion of the Crowbill Hill trail crossing the upper reaches of the* Dryas *step vegetation. Portions of the* Dryas *stripe community are in the center. The talus slope (site 11 trench) is marked by the arrow. August 1980.*

Table 9. Selected chemical data for *Dryas* step-stripe soil profiles, CHT 41 and CHT 135 (Holowaychuk et al. 1966), which are similar to the undisturbed soil in Table 10.

| *Profile* | *Depth (cm)* | *Horizon* | *Organic carbon (%)* | *pH** | *Base saturation (%)* | *Exchangeable Ca (meq/100 g)* |
|---|---|---|---|---|---|---|
| CHT 41 | 28-15 | 01 | 32.7 | 6.0 | 70 | 64.8 |
| | 15-0 | 02 | 32.2 | 5.2 | 61 | 68.0 |
| | 0-15 | Bg | 6.3 | 5.4 | 66 | 21.9 |
| | 15-25 | cf/02f | 19.1 | 5.1 | 58 | 36.0 |
| | 25-45 | cf/02f | 26.5 | 4.5 | 53 | 50.5 |
| CHT 135 | 0-5 | A1 | 8.8 | 6.4 | 73 | 27.7 |
| | 5-20 | B | 3.1 | 6.9 | 83 | 17.9 |
| | 20-35 | B | 2.3 | 9.2 | 84 | 15.9 |
| | 35-53 | C | 2.0 | 7.7 | † | — |
| | 53-68 | C | 1.6 | 7.8 | † | — |

* 1:1 soil:water paste.
† $CaCO_3$ equivalent 0.5%.

Table 10. Soil profiles across site 4, upper portion (*Dryas* step-stripe) of Crowbill Hill trail.
**See Figure 28 for a mechanical analysis and Table 9 for a comparative chemical analysis.**

**Undisturbed**

*Depth of horizon (cm)*

| | |
|---|---|
| 2-0 | Vegetation mat |
| 0-13 A1 | Very dark brown (10 Y 2/2) organic silt loam, moist, friable, weak fine granular structure, abrupt, wavy boundary |
| 13-26 B21 | Very dark grayish brown (10 Y 3/2) fine sandy loam, moist, friable, structureless, 2-5% cobbles, > 10% granules, abrupt, wavy boundary |
| 26-39 BC | Dark grayish brown (10 Y 4/2) and olive brown (2.5 Y 4/4) mixed, fine sandy loam, moist, friable, very weak, fine sub-angular black structure, 10-15% cobbles, abrupt, wavy boundary. |
| 39-54+ IIC1 | Olive brown (2.5 Y 4/4) fine sand, moist, friable, > 25% cobbles. Profile terminated. |

**Disturbed**

*Depth of horizon (cm)*

| | |
|---|---|
| 0-9 A1 | Very dark brown (10 Y 2/2) organic silt loam, friable, 50-60% cobbles, 10% open space, abrupt, wavy boundary. |
| 9-19 A12 | Very dark brown (10 Y 2/2) organic fine sand, loose, > 60% gravel fragments, abrupt, wavy boundary. |
| 19-30 IIBC | Dark brown (10 Y 3/3) organic gravelly fine sand, loose, abrupt, wavy boundary. |
| 30-41+ IIC1 | Dark yellowish brown (10 Y 3/4) gravelly fine sand, wet. Profile terminated. |

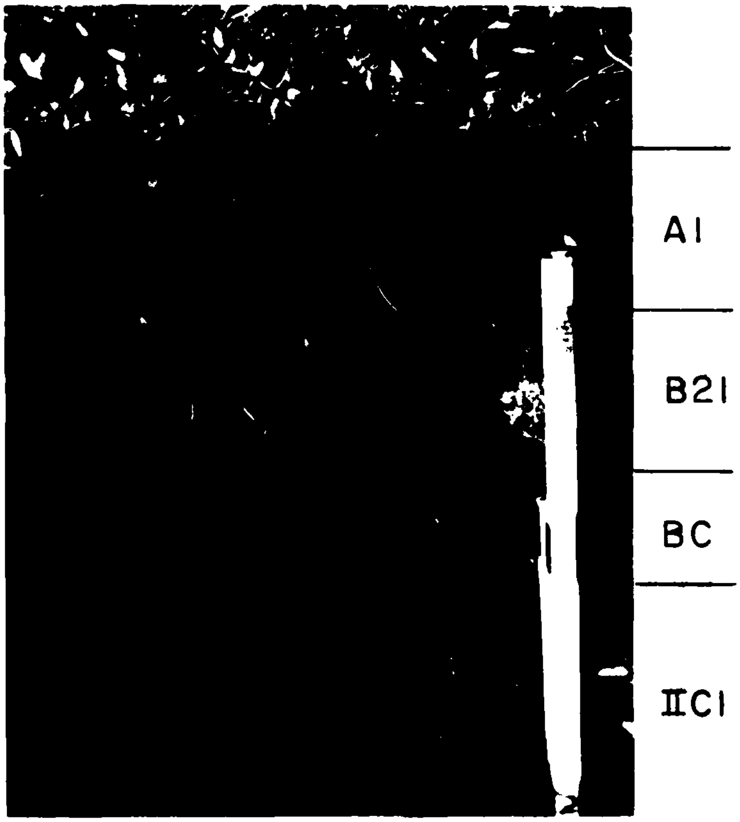



*Figure 22. Pergelic Cryumbrept soil at site 4, Crowbill Hill trail.*

*Castilleja caudata, Eritrichium chamissonis* and *Phlox sibirica. Aulacomnium palustre* is an important moss in the undisturbed tundra.

Revegetation of the trail across the *Dryas* step slope is 80% or more complete (Fig. 20c) but less so as it crosses the *Dryas* stripe area (Fig. 21). The species composition, however, is quite different from the surrounding tundra in both cases. Mosses such as *Bryoerythrophyllum recurvirostrum, Bryum* sp., *Dicranum* sp., *Distichium inclinatum, Encalypta procera, Myurella julacea* and *Timmia* sp. constitute 20% of the area outside of the track. Within the track there is only a thin moss cover composed of such taxa as *Bryobrittonia longipes, Encalypta alpina, Myurella julacea* and *Trematodon brevicollis,* all species reflecting the exposed calcareous substrate of the track. Bryophytes of the moister track areas are *Bryum cryophilum, Philonotis tomentella* and *Drepanocladus revolvens.* Lichens are few in the track areas but make up as much as 10% of the cover in surrounding areas. The grass *Arctagrostis latifolia* constitutes the most conspicuous element of the vegetation on much of the track area. Also included in minor amounts are *Poa glauca, P. arctica, Salix arctica, S. rotundifolia* and *Saxifraga* spp.

The soil profiles in and adjacent to the track (Tables 9 and 10) show that the upper 30 cm of the trail soil, and especially the upper 10 cm, is well drained. It probably represents the modified IIC1 horizon of the undisturbed soil (Fig. 22). The finely divided organic materials mixed (both mechanically and naturally by eluviation since abandonment of the trail) with sandy material provide a nutrient-rich and moist rooting zone. The large component of coarse materials provides both site stability and microsites. Although the IIC1 horizon of the trail profile is wet and lacks roots, it is still better drained than that of the equivalent depth in the undisturbed site.

The most striking physical difference between the profiles is the larger amount of silt- and clay-size materials and the smaller amount of coarse fragments in the undisturbed site (Fig. 23). Most of the finer fractions have been removed from the near-surface horizons by eluviation. The retention of some fines and the organic component probably accounts for the success in revegetation. The

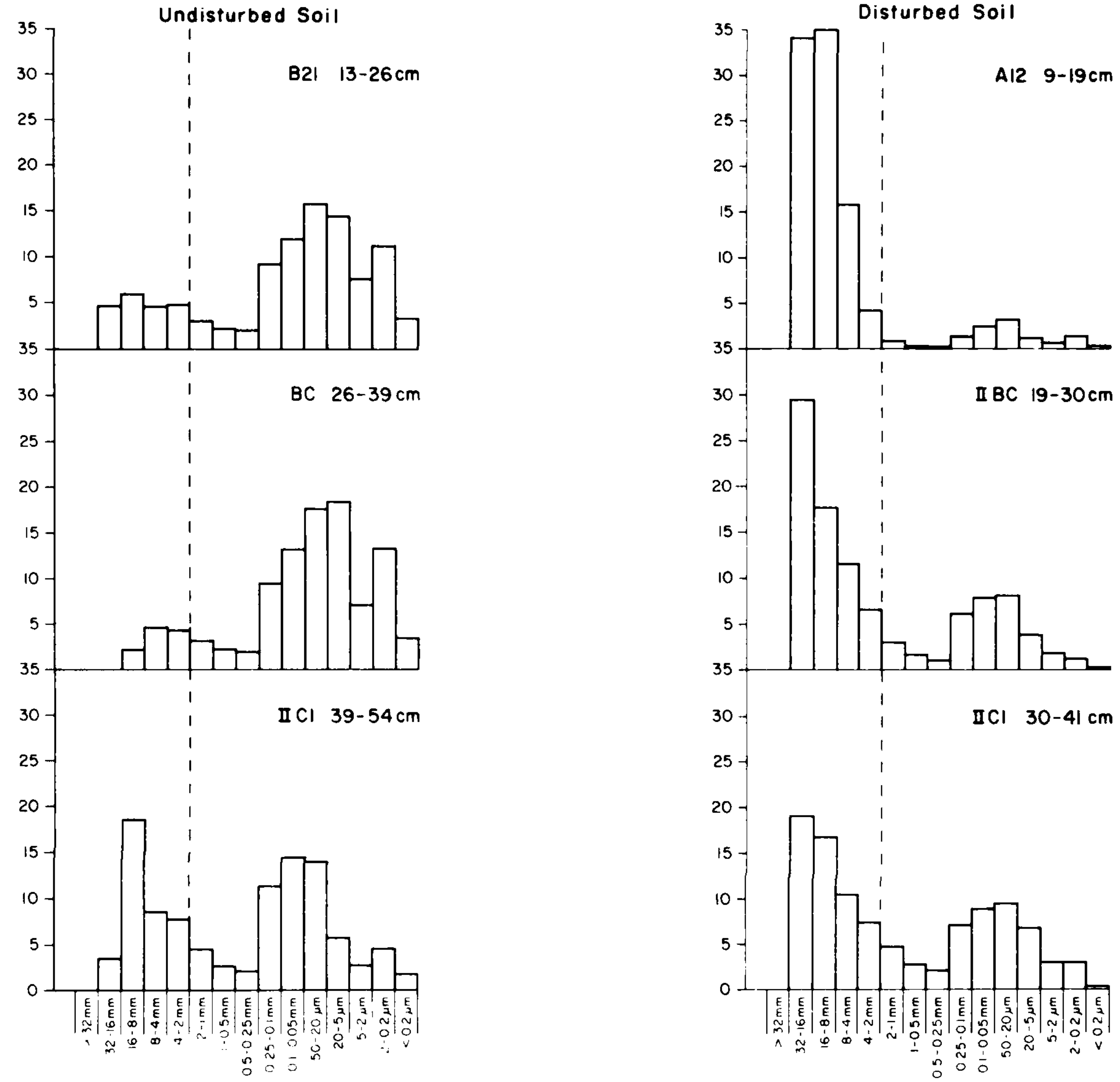


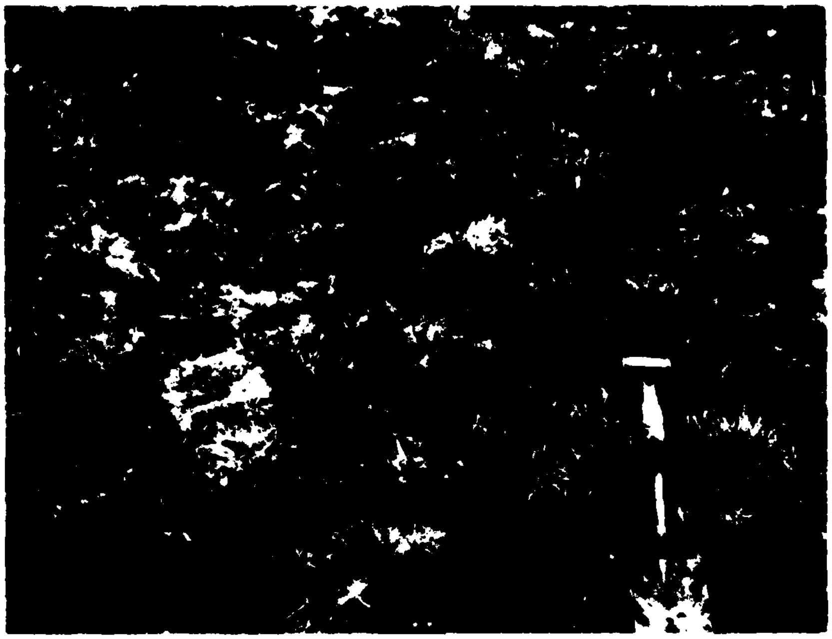

*Figure 23. Histograms comparing the particle size distributions in disturbed trail soil and undisturbed soil.*

bulldozed excavations in this talus lack both ingredients.

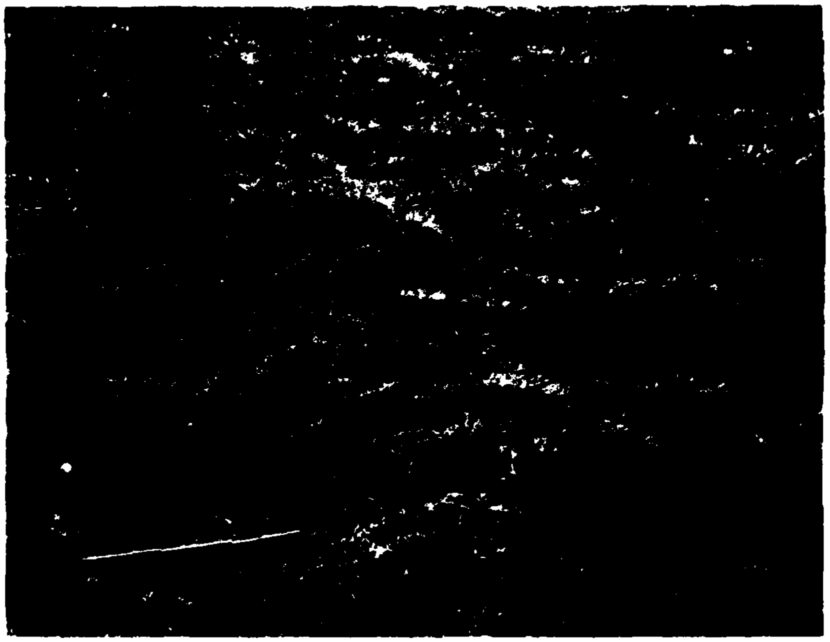
*Sedge tussock tundra trails*

A significant amount of the Ogotoruk Creek service trail crosses sedge tussock tundra, which covers about 40% of the drainage basin (Fig. 12). The vegetation is typical of tussock tundra communities throughout the North Slope, as well as in alpine and taiga areas of interior Alaska. *Eriophorum vaginatum* tussocks are the most conspicuous element of the community. *Ledum decumbens, Betula nana* s.l., *Salix pulchra* and *Vaccinium vitis-idaea* are common on and around the tussocks. In certain wet and/or acid tussock communities *Carex aquatilis, Eriophorum angustifolium* and *Sphagnum* spp. are common; *Sphagnum* is especially common in intertussock areas. Frost scars are also common in most tussock tundra and may account for 30% or more of the surface. Gartner* calculated that frost scar cover is 1-23% in a study at Toolik Lake near the Trans-Alaska Pipeline Haul Road. Frost scars also occur in non-tussock tundra communities.

* Personal communication, CRREL, 1982.



*a. Crushing and abrasion of tussocks as a result of ice road construction in 1977 near Inigok drill site, NPR-A. Considerable tussock recovery has occurred in five years. However,* Sphagnum *has been eliminated in many intertussock areas.*



*b. Compression of tussock tundra at Fish Creek, Alaska, still visible after 30 years. Tussocks have not generally reestablished. August 1977.*

*Figure 24. Damage to tussocks.*

Individual tussocks stand 15–20 cm or more above the surface. In summer, vehicle impact crushes and/or breaks off the tussocks. In winter and spring, when the tussocks are frozen, severe abrasion may occur (Fig. 24a). Reynolds (1981) found that about 50% of sedge tussocks (*Eriophorum vaginatum*) were damaged or killed after winter passage of a seismic tractor train; however, 16 months after the impact there was no significant difference ($P = 0.05$) in the amount of live plants in the track and beyond. In another tussock area, only about 75% recovery was noted after 28 months.

At the site of the Inigok ice road on the North Slope, built in 1977 across tussock tundra, measurable amounts of tussock abrasion and breakage were noted the following summer (Fig. 24a). Perhaps the most significant change in vegetation there, and one that has little visual impact to the casual observer, is the extensive elimination of mosses (especially *Sphagnum* spp. and *Dicranum* spp.) and lichens from the intertussock areas (Everett, unpublished data, 1981).

The more extensively disturbed tussock communities at Ogotoruk Creek (site 11, Fig. 2) show significant recovery in the 20 years since the trail was abandoned, yet the trail is still visible. Areas of the trail that were wetter or contained more ground ice subsided or were compressed up to 0.5 m. In these sites tussock recovery or re-establishment is

*Figure 25. Subsidence of sedge tussock tundra on the Sagwon uplands. The active layer was scraped from the trail in about 1967. Microsite changes have been so drastic that* Carex aquatilis *and in some cases* Arctophila fulva *constitute the recovery species (Hernandez 1973). Similar areas, some showing more subsidence, have been described in ice-rich permafrost at East Oumalik (Lawson 1982).*

*Figure 26. Sedge tussock tundra near the Kokolik River following a natural severe burn in 1978. The convexity of the scars is probably natural. Their apparent accentuation is the result of removal of the interscar and tussock vegetation by fire. Note the density of frost scars (Hall et al. 1978).*

absent or incomplete, and *Eriophorum angustifolium*, *Salix pulchra* and *Carex aquatilis* are the principal taxa. On less-compressed areas *Eriophorum vaginatum* and allied plants have become re-established. This situation is comparable to that at Fish Creek Test Well No. 1, where compression of up to 15 cm is apparent in the tracks 30 years after abandonment (Lawson et al. 1978) (Fig. 24b). At Fish Creek, as on the Sagwon uplands (Fig. 25) where ice wedges appear to be more extensive, thermokarst depressions and pools have developed.

It appears that, barring significant changes in the moisture environment, *Eriophorum vaginatum* tussocks have a good recovery potential, even where severely burned (Fig. 26) (Hall et al. 1978, Johnson 1981, Racine et al. 1983). This rapid recovery, however, may not apply to ancillary species that form the tussock tundra community. In areas of high-ice permafrost, significant subsidence has been noted in burned areas, and it is unlikely tussocks will recover.

## NATURAL STABILITY IN SEDGE TUSSOCK TUNDRA*

Frost scars are characteristic of much of the tussock tundra at Ogotoruk Creek, especially where soil fines are silt and silt loam in texture (Fig. 27). These areas of natural disturbance are little understood. They are probably permanent or semipermanent features that undergo a complex series of events fostering at least temporary revegetation. As such they offer a unique opportunity to study the natural stability of the sedge tussock tundra.

One of the special attributes of the Ogotoruk watershed research area is the substantial amount of environmental documentation that now spans nearly 25 years. This is rare in the North American Arctic. It has permitted the incremental study of frost scar dynamics.

Frost scars, or frost boils (site 9, Fig. 2), are irregular but predominantly oval areas of disturbed soil commonly scattered on the surface in sedge meadow, sedge tussock and ecotone vegetation. In the formal classification of Washburn (1956) they are called nonsorted circles. Nonsorted circles are common and locally abundant in the Ogotoruk Creek valley, especially in sedge tussock tundra, where 50% or more of the surface may be covered by this patterned ground feature. Nonsorted circles of the type described are known from other areas of the Arctic. The best descriptions resembling those features at Ogotoruk Creek were contributed by Hopkins and Sigafoos (1951) from the Seward Peninsula.

Frost scars are usually convex, but they may be flat or depressed. Permafrost is deepest under the center of the scar and shallowest at its margins. These bare areas, which are in such stark contrast to the otherwise complete plant cover of the undisturbed tundra around them, would seem to be ideal places for the germination and establishment of seeds and for the growth of plants. In fact, some frost scars are mostly covered by plants; the majority, however, are not, and a high proportion are almost bare.

Early in the studies at Ogotoruk Creek, it was appreciated that frost features are important parts of the landscape and probably play an important role in the dynamics of the plant communities of the area. Because of the absence of long-term observations, relatively little is known of the details of their history or future, such as their genesis, growth, activity and relationship to environmental variables. The colonization of frost scar surfaces by plants has been observed, but no study has followed individual frost scars for long enough to document plant succession, if it indeed occurs in the traditional sense. Furthermore, the traditional method of substituting space for time in successional studies does not work well in conditions of soil instability. It was decided, therefore, to engage in a long-term study of frost scars and their vegetation.

In 1961 Neiland permanently marked 327 frost scars located in 24 one-acre plots that had been previously established for the study of the vegetation of the Ogotoruk Creek valley (Johnson et al. 1966). She documented the physical details of each scar, mapped its dimensions on a 2-m grid, and described the kinds, amounts and locations of plants on each scar. Each scar was photographed from a fixed point for future reference. In 1962 and 1963 Johnson revisited some of the sites established by Neiland (Table 11) and rephotographed the scars. In 1965 sixty of the scars in four plots were remapped to determine if physical changes in the scars were detectable. In 1972 fifteen of the plots were redescribed, remapped and rephotographed, and in 1980 this was repeated for 13 of the plots. In those 13 plots, 189 of the original 325 frost scars were observed to have changed over the last 20 years (Johnson and Neiland 1983).

In 1965, in an effort to identify any new areas of disturbance that may have occurred, four lines

* Prepared by A.W. Johnson.

*Figure 27. Active frost scars on a pediment slope on the south side of the Ogotoruk Creek valley. More than 50% of the surface is affected. Prominent inter-frost-scar vegetation includes* Salix pulchra, Betula nana *and* Carex *spp.* Rumex *is characteristic of such sites, as is* Petasites frigidus. *A* Carex aquatilis *swath (arrow) marks an old trail. August 1978.*

were established. The areas of disturbance intersecting the lines were measured and recorded. Two of the four lines were located in 1972 and the measurements repeated.

**Occurrence and size of frost scars**

The conditions under which frost scars originate are a matter of some speculation, but it is assumed by some authors (e.g., Hopkins and Sigafoos 1951) that they continue to form and enlarge in the existing climate. This is difficult to state conclusively because few, if any, studies have demonstrated it. If frost scars are forming today at Ogotoruk Creek, one would expect to find a mixture of scar sizes ranging from small, newly formed ones to the largest sizes encountered. This is not the case. Although their sizes vary, scars less than 0.5 m in diameter are only rarely seen. In any event, scars tend to be self-perpetuating because of differences between the temperature-moisture relations of the scars and their better-insulated surroundings.

The areas of bare soil along the four lines established in 1965 were mapped to determine 1) if any new bare areas occurred and 2) if existing bare areas changed in extent. In 1972 two of the lines were again measured (Table 12). Five new bare areas were recorded along transect 3 in 1972, and 78 of the areas of existing bare soil had remained essentially unchanged. The transects were not measured again in 1980, but they should be examined again to determine if the 1972 observations are measurement errors or if they represent newly formed bare areas.

Some of the literature on frost scars assumes that they grow or contract over a period of years.

**Table 11. Location, number and kind of observation of frost scars at Ogotoruk Creek.**

| *Plot no.* | *No. scars* | *1961* | *1962* | *1963* | *1965* | *1972* | *1976* | *1980* |
|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 1,2,3* | 3 | 3 | 1 | 1,2,3 | 3 | 1,2,3 |
| 4 | 13 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | 1,2,3 |
| 12 | 12 | 1,2,3 | 3 | 3 | 1 | 1,2,3 | 3 | 1,2,3 |
| 13 | 12 | 1,2,3 | 3 | 3 | 1 | 1,2,3 | 3 | |
| 18 | 15 | 1,2,3 | 3 | | | 1,2,3 | 3 | 1,2,3 |
| 22 | 11 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | |
| 23 | 15 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | 1,2,3 |
| 24 | 15 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | |
| 25 | 15 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | 1,2,3 |
| 27 | 11 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | |
| 31 | 15 | 1,2,3 | 3 | 3 | 1 | 1,2,3 | 3 | |
| 32 | 15 | 1,2,3 | | | | | 3 | 1,2,3 |
| 35 | 12 | 1,2,3 | | | | | 3 | |
| 36 | 10 | 1,2,3 | | | | | 3 | 1,2,3 |
| 38 | 15 | 1,2,3 | | 3 | | | | 1,2,3 |
| 39 | 13 | 1,2,3 | | 3 | | | 3 | 1,2,3 |
| 43 | 15 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | |
| 44 | 15 | 1,2,3 | 3 | 3 | | 1,2,3 | 3 | |
| 45 | 20 | 1,2,3 | 3 | | | 1,2,3 | 3 | 1,2,3 |
| 46 | 11 | 1,2,3 | 3 | | | 1,2,3 | | 1,2,3 |
| 52 | 15 | 1,2,3 | | 3 | | 1,2,3 | 3 | |
| 54 | 15 | 1,2,3 | | 3 | | | 3 | |
| 55 | 15 | 1,2,3 | 3 | | | | 3 | 1,2,3 |
| Total | 325 | 325 | 240 | 242 | 299 | 59 | 230 | 189 |

*1—Map
2—Description
3—Photograph

**Table 12. Comparison of occurrence of disturbed areas along two transects.**

| *Transect no.* | *No. of disturbed areas in both years* | *Areas found in 1965 but not in 1972* | *Areas found in 1972 but not in 1965* |
|---|---|---|---|
| 1 | 9 | 1 | 0 |
| 3 | 69 | 1 | 5 |

Hopkins and Sigafoos (1951), for example, suggested that a frost scar can be enlarged in favorable years by marginal needle ice formation, and they speak of the "net growth of the many scars."

To test the idea that frost scars grow or contract in one or more directions, maps of frost scar area in 1961, 1972 and 1980 were compared. In neither 1972 nor 1980 was sufficient time available to remap all of the scars. A potentially significant error occurs in making these determinations. The precise margin of a frost scar is often unclear; it may grade into undisturbed tundra without a clear distinction between it and its surroundings. An example of the comparisons is given for one scar as it was mapped in 1961, 1965, 1972 and 1980 (Fig. 28). Relatively little change in the area of this frost scar seems to have taken place. Of course, the time involved is short and the number of frost scars measured is rather small, but the data available from this and other examples support a conclusion that the conditions that occurred at Ogotoruk Creek between 1961 and 1980 did not favor the growth or contraction of frost scars.

One is often misled into believing that new frost scars are forming or growing by the appearance of what looks like, and almost certainly is, new activity within the margins of the scar. At times the combined action of frost heaving due to subsurface segregated ice and needle ice gives the appearance of intense activity on the scar surface. Neither form of cryogenic activity implies expansion of the scar. Scars that seem to have been inactive for some time may show a burst of renewed surface activity. For example, at several locations

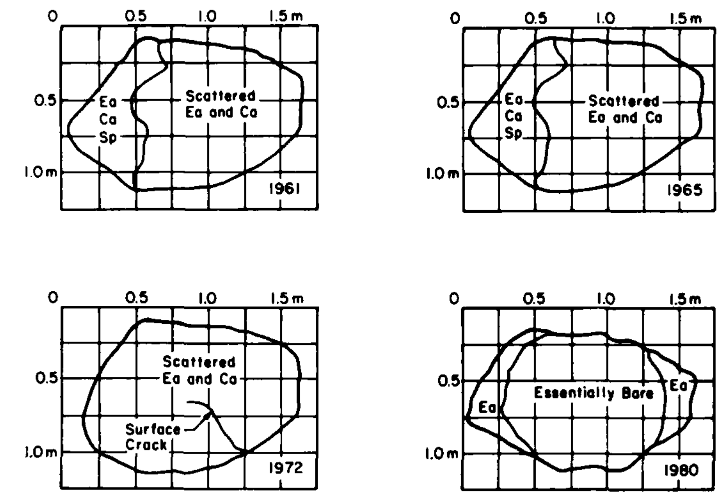



*Figure 28. Plan of frost scar 1-1 in 1961, 1965, 1972 and 1980. The vascular vegetation cover for each year is expressed in percent cover. Ea*—Eriophorum vaginatum, *Ca*—Carex bigelowii, *Sp*—Salix pulchra.

along the Trans-Alaska Pipeline Haul Road, renewed frost scar activity occurred where construction activities blocked drainages and apparently increased the amount of soil moisture in the scar surroundings.

**Plant succession on frost scars**

Plants invade the bare soils of frost scars by direct seeding and by vegetative growth from the surroundings of the scar. The degree to which plant invasion is successful is directly related to the wetness of the site. Scars occurring in sedge meadow vegetation, the wettest of the three sites considered here, show the greatest cover of vegetation (Fig. 29) (Neiland et al. 1962), and those in ecotonal plant communities, the least.

The results of the plant succession study are summarized in Table 13 and Figure 30. Two major conclusions are apparent from these data. First, the proportion of frost scars showing changes in plant cover between 1961 and 1980 is highest in the sedge meadow vegetation type and lowest in the ecotone communities. This, together with the data summarized in Fig. 29, suggests that the availability of moisture may be a controlling factor in plant succession on frost scars. Frost scars in the wettest habitats show the greatest degree of change in plant cover, both positively and negatively. The presence of moisture during the growing season favors plant growth but in the cold periods favors the formation of more soil ice, which disrupts plants (Fig. 31).

Second, the proportion of frost scars (in any vegetation type) that show changes in plant cover increases with time. This is to be expected, of course. In the 20 years of this study the direction of change in plant cover is highly variable on any single scar. The discussion that follows describes only the gross changes that occur on frost scar surfaces. Detailed and quantitative descriptions will await a more extended report.

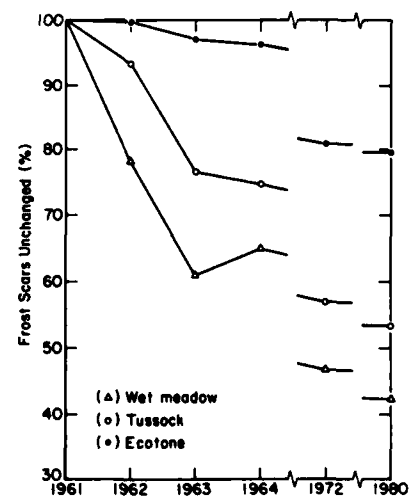



*Figure 29. Percentage of frost scars in three vascular vegetation cover classes.*

Table 13. Summary of changes in plant cover on frost scars of three vegetation types in the Ogotoruk Creek valley from 1961 to 1980 (1962 is first year of comparison).

| | *Wet meadows* | | | | | *Tussock* | | | | | *Ecotone* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *1962* | *1963* | *1964* | *1972* | *1980* | *1962* | *1963* | *1964* | *1972* | *1980* | *1962* | *1963* | *1964* | *1972* | *1980* |
| No. of scars in sample | 89 | 56 | 102 | 78 | 80 | 110 | 116 | 155 | 96 | 78 | 27 | 42 | 54 | 27 | 30 |
| No change | 65 | 36 | 67 | 37 | 34 | 103 | 89 | 116 | 55 | 42 | 27 | 41 | 52 | 22 | 24 |
| Greater plant cover | 17 | 17 | 17 | 17 | 10 | 2 | 4 | 15 | 21 | 12 | 0 | 1 | 2 | 4 | 0 |
| Less plant cover | 3 | 2 | 16 | 22 | 33 | 2 | 12 | 23 | 9 | 17 | 0 | 0 | 0 | 0 | 0 |
| Direction of change uncertain | 4 | 1 | 2 | 2 | 3 | 3 | 11 | 1 | 11 | 7 | 0 | 0 | 0 | 1 | 6 |

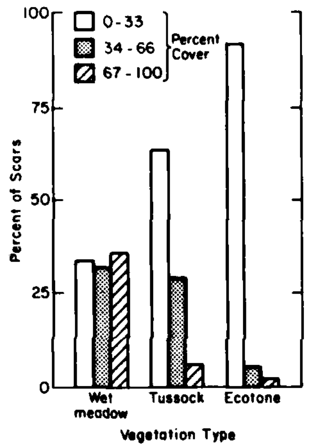
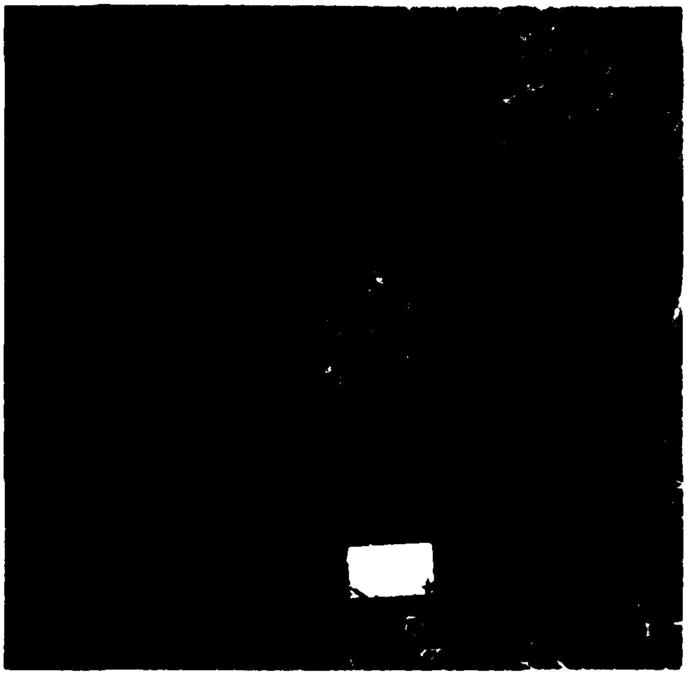
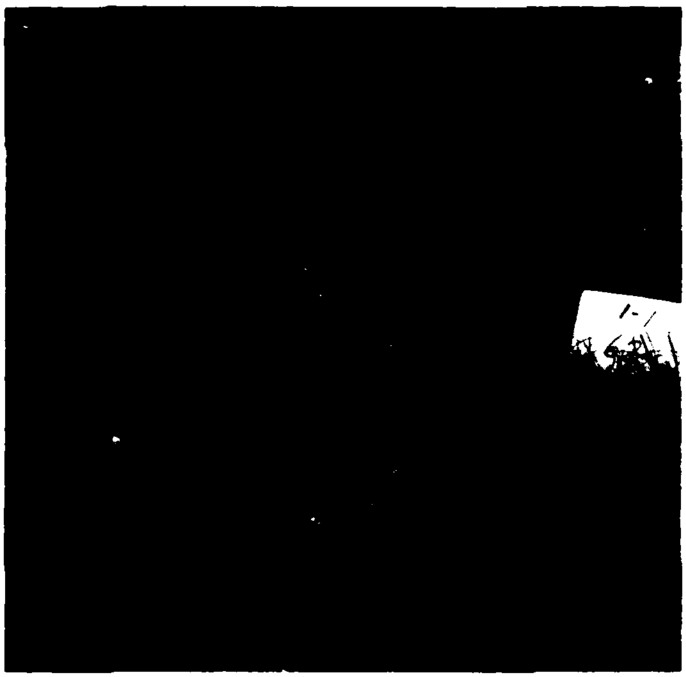



*Figure 30. Percentage of frost scars in which the percent plant cover did not change from 1961 to indicated year.*

*Figure 31. Needle ice development typical of frost-scar surfaces during the period of freeze-up. This development is fostered by high moisture status of silt- and silt-loam-textured soils coupled with intense clear sky radiation at night. This formation is significant in disrupting seedlings on fine-textured surfaces.*



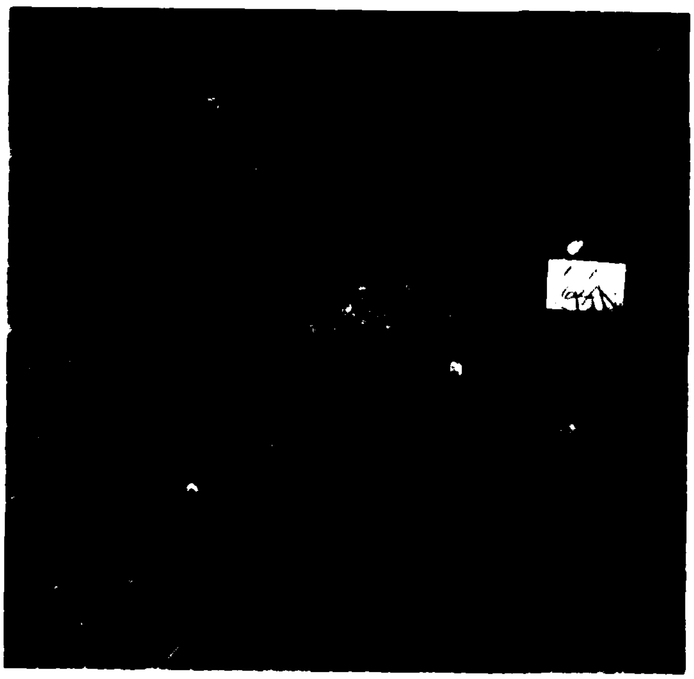
*a. 1961.*



*b. 1962.*

*Figure 32. Plant cover of frost scar 1-1 between 1961 and 1980. After relatively little change in 1962 and 1963, the open area present in 1964 had expanded by 1972; by 1980 the entire scar surface is bare of plants. The graminoid plants are primarily a mixture of* Eriophorum angustifolium *and* Carex aquatilis.

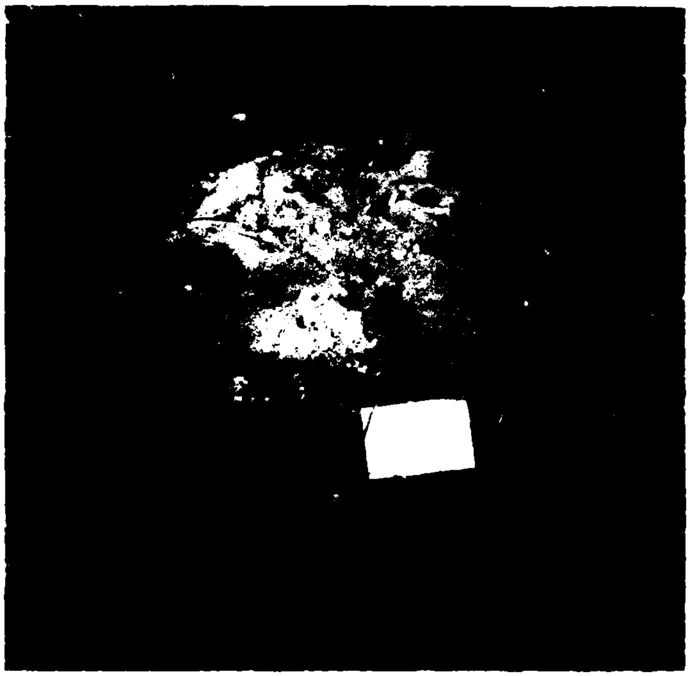
c. 1963.



d. 1964.

Figure 32 (cont'd).

*e. 1972.*



*f. 1980.*

*Figure 32 (cont'd).. Plant cover of frost scar 1-1 between 1961 and 1980. After relatively little change in 1962 and 1963, the open area present in 1964 had expanded by 1972; by 1980 the entire scar surface is bare of plants. The graminoid plants are primarily a mixture of* Eriophorum angustifolium *and* Carex aquatilis.

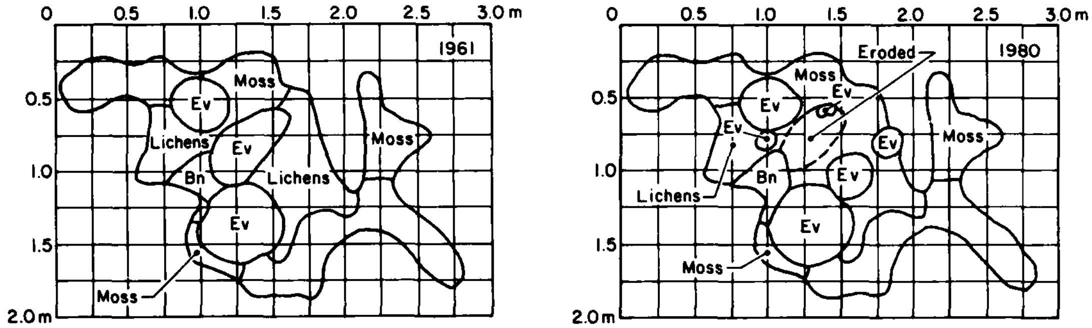



*Figure 33. Frost scar 36-7. One large tussock present in 1961 has almost completely eroded away. Three new tussocks had appeared by 1980. Ev*—Eriophorum vaginatum, *Bn*—Betula nana.

The scars of the sedge meadow (Fig. 29 and 32) show the greatest fluctuations in plant cover of any of the three types. Plant cover on a few of these scars has changed by nearly 100% over the 20-year period. The large changes that occur in this type are nearly always the result of the establishment or loss of one or two major species, particularly *Eriophorum angustifolium* or *Carex aquatilis*. The former seems to be particularly susceptible to being uprooted (or detached from its rhizomes) by needle ice (Fig. 31). At least temporary stability with complete plant cover can develop on scars of this type if they can maintain their cover long enough to produce an organic layer over the bare mineral soil.

On scars occurring in *Eriophorum* tussock vegetation, changes in plant cover generally involve different species than in sedge meadows. Some of the most noticeable changes on scars of this type involve tussock- or bunch-forming species, especially *Eriophorum vaginatum* and *Deschampsia cespitosa*. The latter seeds into the bare surface of the scar and forms small tussocks. These tend to persist and enlarge over several years, but they eventually decompose and are replaced by other tussocks in different locations on the scar. *Eriophorum vaginatum* shows the same kind of behavior, but it is not as abundant an invader as *Deschampsia cespitosa* (Fig. 33). In addition, it persists longer and grows to a much larger size. Because the pattern of change on these scars is more like a loss-and-replacement cycle than an invasion and subsequent elimination, changes in total cover tend to be small. Plant cover in general is less on these scars than on those in the sedge meadow.

Plant cover on scars of the ecotone is very low, and changes are not obvious. Occasionally plants become established, usually by seeds, on these bare gravelly surfaces, but they do not persist for more than a few years. In this respect they are analogous to the runway surfaces. Plants invade from the surroundings of the scar very slowly if at all. The surface of these scars tends to be dry, and the substrate coarse and, during the growing season, very hard. Although little evidence of needle ice formation is seen in any of the scars of this type, they show substantial heaving from subsurface ice during the freeze-up period. Of the three types of scars, the ecotonal ones show the fewest changes over the 20-year period.

## CONCLUSIONS

Wet sites with low species diversity show the greatest recovery potential for vascular plants. Recovery of the cryptogam component of these sites appears to take much longer. There is an indication that recovery in wet sites can extend to reestablishment of surface topography due to subsurface ice build-up. Recovery potential for mesic sites is great if the organic surface materials are not removed but incorporated with the mineral substrate. Fell-fields show relatively little recovery from vehicle disturbance, and the reasons for this are unknown.

Dry constructed surfaces, such as runways, have developed a lag surface and a 10–25% surface cover of a diverse assemblage of dry site and/or pioneer species, of which *Deschampsia cespitosa* is most abundant. It is possible such sites may be fully recovered, although it is likely that shifts in species composition will occur for some time.

Aspect appears to be critical to recovery of spoil piles; recovery is greatest where protected micro-

sites occur. Soil enzyme data confirm the low soil productivity and nutrient availability, which are related to low amounts of organic matter.

Measurements of frost scars, which are natural analogs of disturbance, indicate that the surface activity is high on many frost scars, but the lateral dimensions of the scars do not change, at least within our capability of consistent measurement over 20 years. Neither is there conclusive evidence that new frost scars are forming at present.

Plant succession occurs on frost scars but not in a directional or progressive sense. Rather it appears that plant cover on most frost scars waxes and wanes as year-to-year climatic fluctuations occur. In this respect they may be similar to runways and other constructed surfaces.

The data and observations suggest that plant cover is likely to be highest on frost scars in the wettest habitats and least on those in the driest habitats. Although high levels of soil moisture encourage plant growth, they also create the most favorable conditions for the formation of soil ice, so it is also true that these frost scars show the greatest and fastest changes in plant cover. Frost scars in the driest habitats change the least over time. The idea of cycles of frost scar genesis, activity, invasion and stabilization by plants, and ultimate disappearance is not supported by this study. Indeed the most striking feature of frost scars is their persistence.

The Cape Thompson site and the few other sites with similar disturbances present an opportunity to study the processes and direction of tundra vegetation and an equilibrium of sorts in the associated abiotic environment.

## LITERATURE CITED

**Abramova, A.L. and I.I. Abramov** (1983) *Konspekt Flory Mkhov Mongol'skoi Narodnoi Respubliki* (in Russian). Biologicheskie Resurcy: Prirodnye Usloviia Mongol'skoi Narodnoi Respubliki 17, Nauka, Leningrad.

**Allen, P.W. and R.O. Weedfall** (1966) Weather and climate. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE 481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 9–44.

**Antibus, R.K. and A.E. Linkins** (1978) Ectomycorrhizal fungi of *Salix rotundifolia*. I. Impact of surface applied Prudhoe Bay crude oil on mycorrhizal structure and composition. *Arctic*, **31**: 366–380.

**Antibus, R.K. and A.E. Linkins** (1981) The surface acid phosphatase activities of selected ectomycorrhizal fungi and resynthesized mycorrhizal roots. *Mycological Society of America Symposium, 46th Annual Meetings, Bloomington, Indiana.*

**Antibus, R.K., J. Croxdale, O.K. Miller and A.E. Linkins** (1982) Ectomycorrhizal fungi of *Salix rotundifolia*. III. Surface acid phosphatase activities of fungal isolates and resynthesized roots. *Canadian Journal of Botany*, **59**: 2458–2465.

**Batzli, G.O.** (Ed.) (1980) Patterns of vegetation and herbivory in arctic tundra. Results from the Research on Arctic Tundra Environments (RATE) Program. *Arctic and Alpine Research*, **12**(4): 401–578.

**Bird, C.D.** (1974) Studies on the lichen genus *Evernia* in North Ameria. *Canadian Journal of Botany*, **52**: 2427–2434.

**Bremer, B.** (1980) A taxonomic revision of *Schistidium* (Grimmiaceae, Bryophyta) 2. *Lindbergia*, **6**: 89–117.

**Brodo, I.M. and D.L. Hawksworth** (1977) *Alectoria* and allied genera in North America. *Opera. Botanica*, **42**: 1–164.

**Brown, J., P.C. Miller, L.L. Tieszen and F. Bunnell (Ed.)** (1980) *An Arctic Ecosystem: The Coastal Tundra at Barrow, Alaska*. Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc.

**Buck, W.R.** (1980) Animadversions on *Pterigynandrum* with special commentary on *Forsstroemia* and *Leptopterigynandrum*. *Bryologist*, **83**: 451–465.

**Campbell, R.H.** (1966) Areal geology. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE-481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 57–84.

**Challinor, J.L. and P.L. Gersper** (1975) Vehicle perturbation effects upon a tundra-soil plant system. II. Effects on the chemical regime. *Soil Science Society of America Proceedings*, **39**: 689–695.

**Chapin, F.S., III and M.C. Chapin** (1980) Revegetation of an arctic disturbed site by natural tundra species. *Journal of Applied Ecology*, **17**: 449–456.

**Chapman, R.M. and E.G. Sable** (1960) Geology of the Utukok–Corwin region, northwestern Alas-

ka. U.S. Geologic Survey Professional Paper 303-C, pp. 47-167.

**Cook, W.C.** (1974) Rehabilitation of surface mined land. In *Proceedings of a Workshop on Revegetation of High-Altitude Disturbed Lands.* Environmental Resources Center, Information Series 10, Colorado State University, Fort Collins, pp. 55-58.

**Crow, G.E.** (1978) A taxonomic revision of *Sagina* (Carophyllaceae) in North America. *Rhodora,* **80**: 1-91.

**Drushinina, O.A. and Yu.G. Zharkova** (1979) A study of plant communities of anthropogenic habitats in the area of the Vorkuta industrial center. In *The Effect of Disturbances on Plant Communities in Tundra Regions of the Soviet Union* (G.C. West, Ed.). Biological Papers of the University of Alaska, No. 20, pp. 36-53.

**Ebersole, J.J.** (In prep.) Natural and anthropogenically disturbed vegetation, Oumalik test well, Arctic Coastal Plain, Alaska. Ph.D. dissertation, University of Colorado, Boulder.

**Ebersole, J.J. and P.J. Webber** (1983) Biological decomposition and plant succession following disturbance on the Arctic Coastal Plain, Alaska. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C.: National Academy Press, pp. 266-271.

**Everett, K.R.** (1963) Slope movement in contrasting environments. Ph.D. dissertation, The Ohio State University, Columbus.

**Everett, K.R.** (1964) Slope movement and related phenomena. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE-481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 175-220.

**Everett, K.R.** (1967) The morphology of the slopes of Ogotoruk Creek Valley, northwest Alaska. *Biuletyn Peryglacjalny,* **16**: 117-131.

**Everett, K.R.** (1980a) Distribution and properties of road dust along the northern portion of the haul road. In *Environmental Engineering and Ecological Baseline Investigations Along the Yukon River-Prudhoe Bay Haul Road* (J. Brown and R.L. Berg, Ed.). USA Cold Regions Research and Engineering Laboratory, CRREL Report 80-19, pp. 101-128.

**Everett, K.R.** (1980b) Edaphic factors and their influence on patterns of tundra revegetation. *Proceedings: High-Altitude Revegetation Workshop,* Colorado Water Resources Research Institute, Information Series No. 42, Colorado State University, Fort Collins, pp. 30-37.

**Everett, K.R.** (1980c) Soil-landscape relations at selected sites along environmental gradients in northern Alaska. Final Report to Department of the Army, U.S. Army Research Office, Research Triangle Park, North Carolina.

**Everett, K.R., P.J. Webber, D.A. Walker, R.J. Parkinson and J. Brown** (1978) A geoecological mapping scheme for Alaskan coastal tundra. *Proceedings of the Third International Conference on Permafrost.* National Research Council of Canada, vol. 1, pp. 359-365.

**Flowers, S.** (1973) *Mosses: Utah and the West.* Provo, Utah: Brigham Young University Press.

**Frisvoll, A.A.** (1983) A taxonomic revision of the *Racomitrium canescens* group (Bryophyta, Grimmiales). *Gunneria,* **41**: 1-181.

**Gartner, B.F.** (1982) Controls over revegetation of tundra graminoids in a natural and man-disturbed site in arctic Alaska. M.S. thesis, University of Alaska, Fairbanks.

**Haber, E. and J.E. Cruise** (1974) Generic limits in the Pyroloideae (Ericaciae). *Canadian Journal of Botany,* **52**: 877-883.

**Hall, D., J. Brown and L. Johnson** (1978) The 1977 tundra fire at Kokolik River, Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Special Report 78-10. ADA-062439.

**Hämet-Ahti, L. and V. Virrankoski** (1971) Cytotaxonomic notes on some monocotyledons of Alaska and northern British Columbia. *Annales Botanici Fennici,* **8**: 156-159.

**Herbein, S.B.** (1981) Soil phosphatases: Factors affecting enzyme activity in arctic tussock tundra and Virginia mineral soils. M.S. thesis, Biology Department, Virginia Polytechnic Institute and State University, Blacksburg.

**Hernandez, H.** (1973) Natural plant recolonization of surficial disturbances, Tuktoyaktuk Peninsula region, Northwest Territories. *Canadian Journal of Botany,* **51**: 2177-2196.

**Hok, J.R.** (1969) A reconnaissance of tractor trails and related phenomena on the North Slope of Alaska. U.S. Department of Interior, Bureau of Land Management.

**Hok, J.R.** (1971) Some effects of vehicle operation on Alaskan arctic tundra. M.S. thesis, University of Alaska, Fairbanks.

**Holowaychuk, N., J.H. Pertro, H.R. Finney, R.S. Farnham and P.L. Gersper** (1966) Soils of Ogotoruk Creek watershed. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE 481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 221-273.

**Hong, W.S.** (1984) The genus *Gymnomitrion* in North America, west of the hundredth meridian. *Lindbergia,* **9**: 169–177.

**Hopkins, D.M. and R.S. Sigafoos** (1951) Frost action and vegetation patterns on Seward Peninsula, Alaska. U.S. Geological Survey, Bulletin No. 974-C, pp. 51–100.

**Hultén, E.** (1967) Comments on the flora of Alaska. *Arkiv fur Botanik,* **7**: 1–147.

**Hultén, E.** (1973) Supplement to the flora of Alaska and neighboring territories. *Botaniska Notiser,* **126**: 459–512.

**Inoue, H.** (1976) Chromosome studies in some arctic hepatics. *Bulletin of the Natural Science Museum* (Tokyo), Ser. B. (Botany) **2**(2): 39–46.

**Johnson, A.W., L.A. Viereck, R.E. Johnson and H. Melchior** (1966) Vegetation and flora. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE 481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 277–354.

**Johnson, A.W. and J.G. Packer** (1968) Chromosome numbers in the flora of Ogotoruk Creek, N.W. Alaska. *Botaniska Notiser,* **121**: 403–456.

**Johnson, A.W. and S.A. Kubanis** (1980) Weeds and weedy plants. In *Environmental Engineering and Ecological Baseline Investigations Along the Yukon River–Prudhoe Bay Haul Road* (J. Brown and R.L. Berg, Ed.). USA Cold Regions Research and Engineering Laboratory, CRREL Report 80-19, pp. 132–139. ADA-094497.

**Johnson, A.W. and B.J. Neiland** (1983) An analysis of plant succession on frost scars, 1961–1980. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C.: National Academy Press, pp. 537–542.

**Johnson, L.A.** (1981) Revegetation and selected terrain disturbances along the trans-Alaska pipeline, 1975–1978. USA Cold Regions Research and Engineering Laboratory, CRREL Report 81-12.

**Karczmarz, K.** (1971) A monograph of the genus *Calliergon* (Sull.) Kindb. *Monographiae Botanicae* (Warsaw), **34**: 1–209.

**Karnefelt, I.** (1979) The brown fruticose species of *Cetraria. Opera. Botanica,* **46**: 1–150.

**Komárková, V.** (1983) Recovery of plant communities and summer thaw at the 1949 Fish Creek Test Well 1, arctic Alaska. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C: National Academy Press, pp. 645–650.

**Krog, H.** (1962) A contribution to the lichen flora of Alaska. *Arkiv för Botanik,* Ser. 2, **4**: 489–513.

**Krog, H.** (1968) The macrolichens of Alaska. *Norsk Polarinstitutt Skrifter,* Nr. 144. Oslo.

**Kubanis, S.A.** (1982) Recolonization by native plant species and persistence of introduced species along the Yukon River–Prudhoe Bay haul road, 1977–1981. Abstract, *Proceedings of the 33rd Alaska Science Conference, Fairbanks,* p. 46.

**Kubanis, S.A. and A.W. Johnson** (1980) Recolonization by native and introduced plant species along the Yukon River–Prudhoe Bay haul road. Abstract, *Proceedings of the 30th Alaska Science Conference, Fairbanks,* pp. 89–90.

**Lachenbruch, A.H., G.W. Green and B.Y. Marshall** (1966) Permafrost and the geothermal regimes. In *Environment of the Cape Thompson Region, Alaska* (N.J. Wilimovsky and J.N. Wolfe, Ed.). U.S. Atomic Energy Commission. Available as PNE-481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia, pp. 149–163.

**Lawson, D.E.** (1982) Long-term modifications of perennially frozen sediments and terrain at East Oumalik, northern Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Report 82-36. ADA-123731.

**Lawson, D.E., J. Brown, K.R. Everett, A.W. Johnson, V. Komárková, B.M. Murray, D.F. Murray and P.J. Webber** (1978) Tundra disturbances and recovery following the 1949 exploratory drilling, Fish Creek, northern Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Report 78-28. ADA-065192.

**Linkins, A.E. and N. Fetcher** (1983) Effect of surface-applied Prudhoe Crude oil on vegetation and soil processes in tussock tundra. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C.: National Academy Press, pp. 723–728.

**Linkins, A.E. and J. Neal** (1982) Soil cellulase, chitinase, and protease activity in *Eriophorum vaginatum* tussock tundra at Eagle Summit, Alaska. *Holarctic Ecology,* **5**: 135–138.

**Linkins, A.E., R.M. Atlas and P. Gustin** (1978) Effect of surface applied crude oil on soil and vascular plant root respiration, soil cellulase and aryl hydrocarbon hydroxylase at Barrow, Alaska. *Arctic,* **31**: 355–365.

**Löve, Á.** (1970) Emendations in the Icelandic flora. *Taxon,* **19**: 298–302.
**Löve, Á. and D. Löve** (1975) *Cytotaxonomical Atlas of the Arctic Flora.* Vaduz: J. Cramer.
**Maass, W.S.G.** (1967) Studies on the taxonomy and distribution of *Sphagnum.* IV. *Sphagnum majus, Sphagnum annulatum, Sphagnum mendocinum* and *Sphagnum obtusum* in North America. *Nova Hedwigia,* **14**: 187–214.
**Matveyeva, N.V.** (1979) An annotated list of plants inhabiting sites of natural and anthropogenic disturbances of tundra cover in western Tainigi: The settlement of Kresty. In *The Effect of Disturbances on Plant Communities in Tundra Regions of the Soviet Union* (G.C. West, Ed.). Biological Papers of the University of Alaska, No. 20, pp. 18–29.
**Mexal, J. and C.P.P. Reid** (1973) The growth of selected mycorrhizal fungi in response to induced water stress. *Canadian Journal of Botany,* **53**: 1579–1588.
**Miller, P.C., P. Miller, M. Blake-Jacobson, F.S. Chapin III, K.R. Everett, J. Kummerow, A.E. Linkins, G. Marion, W. Oechel and S.W. Roberts** (In press) A simulation model for plant-soil processes in *Eriophorum vaginatum* tussock tundra in Alaska. *Ecological Monographs.*
**Mulligan, G.A.** (1970) Cytotaxonomic studies of *Draba glabella* and its close allies in Canada and Alaska. *Canadian Journal of Botany,* **48**: 1431–1437.
**Mulligan, G.A.** (1971) Cytotaxonomic studies of the closely allied *Draba cana, D. cinerea,* and *D. groenlandica* in Canada and Alaska. *Canadian Journal of Botany,* **49**: 89–93.
**Mulligan, G.A.** (1974) Confusion in the names of three *Draba* species of the arctic: *D. adamsii, D. oblongata,* and *D. corymbosa. Canadian Journal of Botany,* **52**: 791–793.
**Murray, D.F.** (1980) Threatened and endangered plants of Alaska. U.S. Department of Agriculture and U.S. Department of the Interior.
**Neiland, B.J., A.W. Johnson and R.E. Johnson** (1962) Influence of frost action on the vegetation of the Ogotoruk Creek valley. Unpublished final progress report, Project Chariot.
**Packer, J.G.** (1972) A taxonomic and phytogeographical review of some arctic and alpine *Senecio* species. *Canadian Journal of Botany,* **50**: 507–518.
**Persson, H.** (1962) Bryophytes from Alaska collected by E. Hultén and others. *Svensk Botanisk Tidskrift,* **56**(1): 1–35.
**Persson, H. and K. Holmen** (1961) Bryophytes collected during the arctic field trip of the Ninth International Botanical Congress. *Bryologist,* **64**: 179–198.
**Porsild, A.E.** (1966) Contributions to the flora of southwestern Yukon Territory. *Contributions to Botany IV, National Museum of Canada,* **216**: 1–86.
**Racine, C.H., W.A. Patterson III, and J.G. Dennis** (1983) Permafrost thaw associated with tundra fires in northwest Alaska. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C.: National Academy Press, pp. 1024–1029.
**Reynolds, P.C.** (1981) Some effects of oil and gas exploration activities on tundra vegetation in northern Alaska. Unpublished paper presented at SPIB meeting, Denver, Colorado.
**Steere, W.C.** (1965) The boreal bryophyte flora as affected by Quaternary glaciation. In *The Quaternary of the United States* (H.E. Wright, Jr. and D.G. Frey, Ed.). Princeton, New Jersey: Princeton University Press, pp. 485–495.
**Steere, W.C.** (1976) Ecology, phytogeography and floristics of arctic Alaskan bryophytes. *Journal of the Hattori Botanical Laboratory,* **41**: 47–72.
**Steere, W.C.** (1977) *Garysmithia bifurcata,* a new genus and species of Leskeaceae (Musci) from Alaska and Colorado. *Phytologia* **36**: 165–170.
**Steere, W.C.** (1978) The mosses of arctic Alaska. *Bryophytorum Bibliotheca* 14. J. Cramer, Vaduz. 508 pp.
**Steere, W.C. and H. Inoue** (1974) *Fossombronia alaskana,* a new hepatic from arctic Alaska. *Bryologist,* **77**: 63–71.
**Steere, W.C. and G.R. Brassard** (1976) *Schistidium holmenianum,* sp. nov. from arctic North America. *Bryologist,* **79**: 208–214.
**Steere, W.C. and H. Inoue** (1978) The Hepaticae of arctic Alaska. *Journal of the Hattori Botanical Laboratory,* **44**: 251–345.
**Thomson, J.W.** (1979) *Lichens of the Alaskan Arctic Slope.* Ontario, Canada: University of Toronto Press.
**Thomson, J.W. and C.D. Bird** (1978) The lichen genus *Dactylina* in North America. *Canadian Journal of Botany,* **56**: 1602–1624.
**Tieszen, L.L. (Ed.)** (1978) *Vegetation and Production Ecology of an Alaskan Arctic Tundra.* Ecological Studies 29. New York: Springer-Verlag.
**Van Cleve, K.** (1972) Revegetation of disturbed tundra and taiga surfaces by introduced and native plant species. In *Proceedings of the Symposi-*

*um on the Impact of Oil Resource Development on Northern Plant Communities, 23rd AAAS Science Conference, Fairbanks, Alaska.*

**Vitt, D.H.** (1976) The genus *Seligeria* in North America. *Lindbergia,* **3**: 241-275.

**Wahrhaftig, C.** (1965) Physiographic divisions of Alaska. U.S. Geological Survey, Professional Paper 482.

**Walker, D.A.** (1983) A hierarchical tundra vegetation classification especially designed for mapping in northern Alaska. *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska.* Washington, D.C.: National Academy Press, pp. 1332-1337.

**Walker, D.A., K.R. Everett, P.J. Webber and J. Brown** (1980) Geobotanical atlas of the Prudhoe Bay region, Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Report 80-14.

**Walker, D.A., W. Acevedo, K.R. Everett, L. Gaydos, J. Brown and P.J. Webber** (1982) Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Report 82-37.

**Washburn, A.L.** (1956) Classification of patterned ground and review of suggested origins. *Bulletin of the Geological Society of America,* **67**: 823-866.

**Wilimovsky, N.J. and J.N. Wolfe (Ed.)** (1966) *Environment of the Cape Thompson Region, Alaska.* U.S. Atomic Energy Commission. Available as PNE-481, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia.

**Yurtsev, B.A. and A.A. Korobkov** (1979) An annotated list of plants inhabiting sites of natural and anthropogenic disturbances of tundra cover: southeasternmost Chukchi Peninsula. In *The Effect of Disturbances of Plant Communities in Tundra Regions of the Soviet Union* (G.C. West, Ed.). Biological Papers of the University of Alaska, No. 20, pp. 1-17.

## APPENDIX A: CHECKLIST OF BRYOPHYTES AND LICHENS OF THE OGOTORUK CREEK REGION

B.M. Murray

The Ogotoruk Creek region is floristically very rich. There is a large array of habitats and microhabitats with differing substrates, pH, moisture regimes, etc., in both alpine and littoral landscapes. The only previous list of bryophytes and lichens for the area was made by Johnson et al. (1966). They reported 13 hepatics, 79 mosses and 72 lichens. No lichenologist had visited the area prior to 1980, but the bryophytes are quite well known due to the visits of the renowned bryologist and arctic specialist, W.C. Steere, and his colleagues, G.L. Smith, H. Inoue, and Z. Iwatsuki, in the 1960s and 1970s. Largely through their efforts the bryophyte flora was greatly expanded and was reported in the following papers: Persson and Holmen (1961), Persson (1962), Maass (1967), Steere and Inoue (1974), Inoue (1976), Steere and Brassard (1976), Vitt (1976), Steere (1977), Steere (1978), Steere and Inoue (1978), Bremer (1980), Frisvoll (1983) and Hong (1984). Lichens based on collections of Hultén; Johnson, Viereck and Melchior; and Viereck and Bucknell were reported in several papers (Johnson et al. 1966, Krog 1968, Bird 1974, Thomson and Bird 1978).

The following checklist has been compiled from the literature, with the 1980 collections cited only for additions to the flora of the region. These new reports are preceded by an asterisk. The list comprises 65 hepatics, 247 mosses (including 14 new reports), and 129 lichens (including 33 new records). Four mosses and four lichens previously reported are here treated as doubtful or rejected taxa. There has unfortunately been too little time to complete identifying all 1000 collections (the bulk of this report was submitted in January 1981), so there will probably be many additions to this preliminary list, especially saxicolous crustose lichens. Notes on the most taxonomically or geographically interesting species follow the checklist. Murray specimens are in the Herbarium of the University of Alaska Museum.

### BRYOPHYTES

*Hepatics*

**Herbertaceae**
*Herbertus sakuraii* (Warnst.) Hattori ssp. *arcticus*
Steere and Inoue 1978

**Pseudolepicoleaceae**
*Blepharostoma trichophyllum* (L.) Dumort.
Inoue 1976, Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

**Ptilidiaceae**
*Ptilidium ciliare* (L.) Hampe
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

**Lophoziaceae**
*Anastrophyllum minutum* (Cranz) Schust.
Persson 1962 as *Sphenolobus,* Steere and Inoue 1978

*Anastrophyllum minutum* (Cranz) Schust., var. *grandis* (Gottsche ex Lindb.) Schust.
Steere and Inoue 1978

*Gymnocolea inflata* (Huds.) Dumort.
Inoue 1976, Steere and Inoue 1978

*Lophozia atlantica* (Kaal.) Schiffn.
Persson 1962 as *Orthocaulis*

*Lophozia attenuata* (Mart.) Dumort.
Steere and Inoue 1978

*Lophozia barbata* (Schmid.) Dumort.
Inoue 1976, Persson 1962, Steere and Inoue 1978

*Lophozia ehrhartiana* (Web.) Inoue & Steere
Steere and Inoue 1978

*Lophozia groenlandica* (Nees in G., L. & N.) Macoun
Persson 1962

*Lophozia guttulata* (Lindb. & Arnell) Evans
Steere and Inoue 1978

*Lophozia heterocolpa* (Thed.) Howe
Steere and Inoue 1978, Inoue 1976

*Lophozia heterocolpa* var. *harpanthoides* (Bryhn & Kaal.) Schust.
Persson 1962 as *Leiocolea*

*Lophozia incisa* (Schrad.) Dumort
Johnson et al. 1966, Steere and Inoue 1978

*Lophozia kunzeana* (Huben) Evans
Steere and Inoue 1978

*Lophozia latifolia* Schust.
Steere and Inoue 1978

*Lophozia longidens* (Lindb.) Macoun
Steere and Inoue 1978

*Lophozia opacifolia* Culmann
Steere and Inoue 1978

*Lophozia polaris* (Schust.) Schust. & Damsholt
Steere and Inoue 1978

*Lophozia quadriloba* (Lindb.) Evans
Inoue 1976, Persson 1962 as *Orthocaulis,* Steere and Inoue 1978

*Lophozia ventricosa* (Dicks.) Dumort.
Inoue 1976, Steere and Inoue 1978

*Lophozia wenzelii* (Nees) Steph.
Steere and Inoue 1978

*Tritomaria quinquedentata* (Huds.) Buch
Persson 1962, Steere and Inoue 1978

*Tritomaria scitula* (Tayl.) Joerg.
Persson 1962

**Mesoptychiaceae**
*Mesoptychia sahlbergii* (Lindb. & Arnell) Evans
Inoue 1976, Steere and Inoue 1978

**Jungermanniaceae**
*Jungermannia subelliptica* (Lindb. ex Kaal.) Levier
Steere and Inoue 1978

*Nardia geoscyphus* (De Not.) Lindb. in Carr.
Persson 1962

**Gymnomitriaceae**
*Gymnomitrion coralloides* Nees
Hong 1984

*Marsupella arctica* (Berggr.) Bryhn & Kaal.
Johnson et al. 1966, Persson 1962, Persson and Holmen 1961, Steere and Inoue 1978

*Marsupella emarginata* var. *aquatica* (Lindenb.) Dumort.
Steere and Inoue 1978

**Scapaniaceae**
*Diplophyllum taxifolium* (Wahlenb.) Dumort.
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Scapania apiculata* Spruce
Steere and Inoue 1978

*Scapania crassiretis* Bryhn
Steere and Inoue 1978

*Scapania curta* (Mart.) Dumort.
Persson 1962

*Scapania cuspiduligera* (Nees) K. Muell.
Inoue 1976, Persson 1962, Steere and Inoue 1978

*Scapania gymnostomophila* Kaal.
Steere and Inoue 1978

*Scapania hyperborea* Joerg.
Steere and Inoue 1978

*Scapania obcordata* (Berggr.) S. Arn.
Steere and Inoue 1978

*Scapania paludicola* Loeske & K. Muell.
Inoue 1976, Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Scapania paludosa* (K. Muell.) K. Muell.
Steere and Inoue 1978

*Scapania parvifolia* Warnst.
Steere and Inoue 1978

*Scapania simmonsii* Bryhn & Kaal.
Inoue 1976, Steere and Inoue 1978

**Plagiochilaceae**
*Plagiochila arctica* Bryhn & Kaal.
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Plagiochila porelloides* (Torrey ex Nees) Lindenb.
Persson 1962

**Arnelliaceae**
*Arnellia fennica* (Gottsche) Lindb.
Inoue 1976, Persson 1962, Steere and Inoue 1978

**Antheliaceae**
*Anthelia julacea* (L.) Dumort.
Inoue 1976, Steere and Inoue 1978

*Anthelia juratzkana* (Limpr.) Trev.
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

**Cephaloziaceae**
*Cephalozia pleniceps* (Aust.) Lindb.
Steere and Inoue 1978

*Odontoschisma elongata* (Lindb.) Evans
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Odontoschisma macounii* (Aust.) Underw.
Johnson et al. 1966

**Cephaloziellaceae**
*Cephaloziella arctica* Bryhn & Douin
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Cephaloziella divaricata* (Sm.) Schiffn.
Persson 1962

*Cephaloziella subdentata* Warnst.
Persson 1962

**Radulaceae**
*Radula complanata* (L.) Dumort.
Steere and Inoue 1978

*Radula prolifera* Arnell
Inoue 1976, Steere and Inoue 1978

**Porellaceae**
*Ascidiota blepharophylla* Massal.
Persson 1962, Steere 1976

**Codoniaceae**
*Fossombronia alaskana* Steere & Inoue
Inoue 1976, Steere and Inoue 1974, Steere and Inoue 1978

**Allisoniaceae**
*Calycularia laxa* Lindb. & Arnell
Steere and Inoue 1978

**Pallaviciniaceae**
*Moerckia flotowiana* (Nees) Schiffn.
Steere and Inoue 1978

**Aneuraceae**
*Aneura pinguis* (L.) Dumort
Persson 1962, Steere and Inoue 1978

*Riccardia latifrons* (Lindb.) Lindb.
Johnson et al. 1966, Persson 1962

**Cleveaceae**
*Sauteria alpina* (Nees) Nees
Persson 1962, Steere and Inoue 1978

**Marchantiaceae**
*Marchantia polymorpha* L.
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Preissia quadrata* (Scop.) Nees
Johnson et al. 1966, Persson 1962, Steere and Inoue 1978

*Mosses*

**Sphagnaceae**
*Sphagnum aongstroemii* C. Hartm.
Steere 1978

*Sphagnum balticum* (Russ.) Russ. ex C. Jens.
Johnson et al. 1966

*Sphagnum compactum* DC. ex Lam. & DC.
Johnson et al. 1966

*Sphagnum fimbriatum* Wils. ex. J. Hook.
Johnson et al. 1966, Steere 1978

*Sphagnum fuscum* (Schimp.) Klinggr.
Johnson et al. 1966

*Sphagnum girgensohnii* Russ.
Johnson et al. 1966, Steere 1978

*Sphagnum imbricatum* Hornsch. ex Russ.
Johnson et al. 1966, Persson 1962, Steere 1978

*Sphagnum lenense* H. Lindb. ex Pohle
Johnson et al. 1966

*Sphagnum magellanicum* Brid.
Johnson et al. 1966, Persson 1962

*Sphagnum nemoreum* Scop.
Johnson et al. 1966

*Sphagnum obtusum* Warnst.
Johnson et al. 1966, Maass 1967, Persson 1962

*Sphagnum rubellum* Wils.
Johnson et al. 1966, Persson 1962, Steere 1978

*Sphagnum squarrosum* Crome
Johnson et al. 1966, Persson 1962, Steere 1978

*Sphagnum subsecundum* Nees ex Sturm
Johnson et al. 1966, Persson 1962, Steere 1978

*Sphagnum warnstorfii* Russ.
Johnson et al. 1966, Persson 1962

**Andreaeaceae**

* *Andreaea alpestris* (Thed.) Schimp.
Johnson, Viereck and Melchior 464 (ALA,S); Steere 63-555 (ALTA, NY); Steere, Inoue and Iwatsuki 73-210 (ALTA, NY)

*Andreaea rupestris* Hedw. var. *papillosa* (Lindb.) Podp.
Murray 10,264, 10,277; Steere, Inoue and Iwatsuki 73-177 (NY)

**Fissidentaceae**

*Fissidens adianthoides* Hedw.
Steere 1978

*Fissidens bryoides* Hedw.
Steere 1978

*Fissidens osmundoides* Hedw.
Persson 1962, Steere 1978

**Ditrichaceae**

*Ceratodon purpureus* (Hedw.) Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

*Distichum capillaceum* (Hedw.) B.S.G.
Steere 1978

*Distichum hagenii* Ryan ex Philib.
Steere 1978

*Distichum inclinatum* (Hedw.) B.S.G.
Persson 1962, Steere 1978

*Ditrichum flexicaule* (Schwaegr.) Hampe
Persson 1962, Steere 1978

*Trichodon cylindricus* (Hedw.) Schimp.
Steere 1978

**Seligeriaceae**

*Seligeria polaris* Berggr.
Steere 1978

* *Seligeria pusilla* (Hedw.) B.S.G.
Murray 10,064

*Seligeria subimmersa* Lindb.
Steere 1978, Vitt 1976

**Dicranaceae**

*Campylopus schimperi* Milde
Steere 1978

*Cynodontium glaucescens* (Lindb. & Arn.) Paris
Steere 1978

*Cynodontium polycarpum* (Hedw.) Schimp.
Steere 1978

*Cynodontium strumiferum* (Hedw.) Lindb.
Steere 1978

*Dichodontium pellucidum* (Hedw.) Schimp.
Steere 1978

*Dicranella crispa* (Hedw.) Schimp.
Persson 1962, Steere 1978

*Dicranella schreberiana* (Hedw.) Schimp.
Steere 1978

*Dicranella subulata* (Hedw.) Schimp.
Steere 1978

*Dicranoweisia cirrata* (Hedw.) Lindb. ex Milde
Steere 1978

*Dicranoweisia crispula* (Hedw.) Lindb. ex Milde
Persson 1962

*Dicranum acutifolium* (Lindb. & Arnell) C. Jens. ex Weinm.
Persson 1962, Steere 1978

*Dicranum angustum* Lindb.
Persson 1962, Steere 1978

*Dicranum elongatum* Schleich. ex Schwaegr.
Johnson et al. 1966, Persson 1962, Steere 1978

*Dicranum fuscescens* Turn.
Persson 1962

*Dicranum groenlandicum* Brid.
Persson 1962

*Dicranum majus* Sm.
Johnson et al. 1966, Persson 1962, Steere 1978

*Dicranum muehlenbeckii* B.S.G.
Steere 1978

*Dicranum scoparium* Hedw.
Steere 1978

*Dicranum undulatum* Brid.
Steere 1978

*Oncophorus virens* (Hedw.) Brid.
Steere 1978

*Oncophorus wahlenbergii* Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

*Trematodon brevicollis* Hoppe & Hornsch. ex Hornsch.
Steere 1978

**Encalyptaceae**
*Bryobrittonia longipes* (Mitt.) Horton
Persson 1962, Steere 1978

*Encalypta affinis* R. Hedw.
Persson 1962, Steere 1978

*Encalypta alpina* Sm.
Persson 1962, Steere 1978

***Encalypta brevicolla* (B.S.G.) Bruch ex Aongstr.
Murray 9616, 9974, 10,245

***Encalypta brevipes* Schljak.
Murray 9613, 9978, 10,202

*Encalypta ciliata* Hedw.
Steere 1978

***Encalypta mutica* Hag.
Murray 9761

*Encalypta procera* Bruch
Steere 1978

*Encalypta rhaptocarpa* Schwaegr.
Johnson et al. 1966, Persson 1962, Steere 1978

**Pottiaceae**

*Aloina brevirostris* (Hook. & Grev.) Kindb.
Persson 1962, Steere 1978

*Barbula icmadophila* Schimp. ex C. Muell.
Johnson et al. 1966, Persson 1962, Steere 1978

*Bryoerythrophyllum recurvirostrum* (Hedw.) Chen.
Persson 1962, Steere 1978

*Desmatodon laureri* (Schultz) B.S.G.
Steere 1978

*Desmatodon leucostoma* (R. Br.) Berggr.
Steere 1978

*Didymodon asperifolius* (Mitt.) Crum, Steere & Anderson
Persson 1962 as *Barbula rufa,* Steere 1978

*Didymodon johansenii* (Williams) Crum
Steere 1978

*Geheebia gigantea* (Funck) Boul.
Steere 1978

*Hymenostylium recurvirostrum* (Hedw.) Dix.
Steere 1978

***Phascum cuspidatum* Hedw.
Murray 9920, 10,393b

***Pottia* cf. *arizonica* Wareh. var. *mucronulata* Wareh.
Murray 9852, 9921

*Pottia heimii* (Hedw.) B.S.G.
Persson 1962, Steere 1978

*Pottia obtusifolia* (R. Br.) C. Muell.
Persson 1962 as *P. obtusa*

*Pterygoneurum lamellatum* (Lindb.) Jur.
Steere 1978

*Stegonia latifolia* (Schwaegr. ex Schultes) Vent. ex Broth.
Steere 1978

*Stegonia pilifera* (Dicks.) Crum, Steere & Anderson
Steere 1978

*Tortella arctica* (Arnell) Crundw. & Nyh.
Persson 1962, Steere 1978

*Tortella fragilis* (Drumm.) Limpr.
Persson 1962, Steere 1978

*Tortella tortuosa* (Hedw.) Limpr.
Steere 1978

*Tortula mucronifolia* Schwaegr.
Persson 1962, Steere 1978

*Tortula ruralis* (Hedw.) Gaertn., Meyer & Scherb.
Persson 1962, Steere 1978

*Trichostomum arcticum* Kaal.
Persson 1962 as *T. cuspidatissimum*, Steere 1978

**Grimmiaceae**
*Grimmia affinis* Hoppe & Hornsch. ex Hornsch.
Johnson et al. 1966, Persson 1962, Steere 1978

*Racomitrium canescens* (Timm ex Hedw.) Brid. ssp. *latifolium* (C. Jens.) Frisvoll
Frisvoll 1983

* *Racomitrium ericoides* (Web. ex Brid.) Brid.
Murray 10,167, 10,209, 10,490, det. A.A. Frisvoll

*Racomitrium heterostichum* (Hedw.) Brid.
Persson 1962, Steere 1978

*Racomitrium lanuginosum* (Hedw.) Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

*Racomitrium panschii* (C. Muell.) Kindb.
Frisvoll 1983

*Schistidium apocarpum* (Hedw.) B.S.G.
Persson 1962, Steere 1978

*Schistidium gracile* (Rohl.) Limpr.
Persson 1962 as *S. strictum*, Steere 1978

*Schistidium holmenianum* Steere & Brassard
Bremer 1980, Steere and Brassard 1976, Steere 1978

*Schistidium rivulare* (Brid.) Podp. ssp. *latifolium* (Zet.) B. Bremer
Steere 1978 as *S. platyphyllum*

*Schistidium rivulare* (Brid.) Podp. ssp. *rivulare*
Persson 1962, Steere 1978 as *S. alpicola*

*Schistidium tenerum* (Zett.) Nyholm
Bremer 1980, Persson 1962, Steere 1978

**Funariaceae**
*Funaria arctica* (Berggr.) Kindb.
Persson 1962, Steere 1978

*Funaria hygrometrica* Hedw.
Steere 1978

**Splachnaceae**
*Aplodon wormskjoldii* (Hornem.) R. Brown
Johnson et al. 1966, Persson 1962, Steere 1978 as *Haplodon*

*Splachnum sphaericum* Hedw.
Johnson et al. 1966 as *S. ovatum*, Steere 1978

*Splachnum vasculosum* Hedw.
Steere 1978

*Tayloria serrata* (Hedw.) B.S.G.
Persson 1962 as *T. tenuis*, Steere 1978

*Tetraplodon angustatus* (Hedw.) B.S.G.
Johnson et al. 1966, Persson 1962

*Tetraplodon mnioides* (Hedw.) B.S.G.
Johnson et al. 1966, Persson 1962, Steere 1978

*Tetraplodon pallidus* Hag.
Persson 1962, Steere 1978

*Tetraplodon paradoxus* (R. Br.) Hag.
Johnson et al. 1966, Persson 1962, Steere 1978

*Tetraplodon urceolatus* (Hedw.) B.S.G.
Steere 1978

*Voitia hyperborea* Grev. & Arnott
Steere 1978

**Bryaceae**
*Bryum algovicum* Sendtn. ex. C. Muell.
Steere 1978

*Bryum arcticum* (R. Br.) B.S.G.
Persson 1962, Steere 1978

* *Bryum argenteum* Hedw.
Murray 10,194

*Bryum calophyllum* R. Br.
Steere 1978

*Bryum cryophilum* Mart.
Persson 1962, Steere 1978

*Bryum cyclophyllum* (Schwaegr.) B.S.G.
Steere 1978

*Bryum knowltonii* Barnes
Steere 1978

* *Bryum lisae* De Not. var. *cuspidatum* (B.S.G.) Marg.
Murray 9928, det. H. Ochi

*Bryum pallens* (Brid.) Sw. ex Roehl.
Steere 1978

*Bryum pallescens* Schleich. ex Schaegr.
Johnson et al. 1966, Steere 1978

*Bryum pseudotriquetrum* (Hedw.) Gaertn., Meyer & Scherb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Bryum salinum* Hag. ex Limpr.
Johnson et al. 1966, Persson 1962, Steere 1978

*Bryum stenotrichum* C. Muell.
Steere 1978

* *Bryum uliginosum* (Brid.) B.S.G.
Johnson, Viereck and Melchior 544 (ALA), det. H. Ochi

*Leptobryum pyriforme* (Hedw.) Wils
Persson 1962, Steere 1978

*Mniobryum wahlenbergii* (Web. & Mohr) Jenn
Persson 1962 as *Pohlia albicans*, Steere 1978

*Plagiobryum demissum* (Hook.) Lindb.
Persson 1962, Steere 1978

* *Pohlia andrewsii* J. Shaw
Steere 1978 as *P. annotina*

*Pohlia cruda* (Hedw.) Lindb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Pohlia crudoides* (Sull. & Lesq.) Broth.
Steere 1978

*Pohlia nutans* (Hedw.) Lindb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Pohlia proligera* (Kindb. ex Limpr.) Lindb. ex Arnell
Persson 1962, Steere 1978

*Pohlia filum* (Schimp.) Mart.
Steere 1978 as *P. schleicheri*

**Mniaceae**
*Cinclidium arcticum* (B.S.G.) Schimp.
Persson 1962, Steere 1978

*Cinclidium latifolium* Lindb.
Steere 1978

*Cinclidium stygium* Sw.
Steere 1978

*Cinclidium subrotundum* Lindb.
Steere 1978

*Cyrtomnium hymenophylloides* (Huebn.) Nyholm
Steere 1978

*Cyrtomnium hymenophyllum* (B.S.G.) Holmen
Persson 1962, Steere 1978

*Mnium blyttii* B.S.G.
Persson 1962, Steere 1978

*Mnium spinosum* (Voit ex Sturm) Schwaegr.
Steere 1978

*Mnium thomsonii* Schimp.
Persson 1962, Steere 1978

*Plagiomnium ellipticum* (Brid.) Kop.
Persson 1962, Steere 1978

*Plagiomnium medium* (B.S.G.) Kop.
Johnson et al. 1966, Persson 1962, Steere 1978

*Pseudobryum cinclidioides* (Huebn.) Kop.
Steere 1978

*Rhizomnium andrewsianum* (Steere) Kop.
Steere 1978

**Aulacomniaceae**
*Aulacomnium acuminatum* (Lindb. & Arnell.) Kindb.
Persson 1962, Steere 1978

*Aulacomnium palustre* (Hedw.) Schwaegr.
Johnson et al. 1966, Persson 1962, Steere 1978

*Aulacomnium turgidum* (Wahlenb.) Schwaegr.
Johnson et al. 1966, Persson 1962, Steere 1978

**Meesiaceae**
*Meesia triquetra* (Richt.) Aongstr.
Johnson et al. 1966, Persson 1962, Steere 1978

*Meesia uliginosa* Hedw.
Johnson et al. 1966, Persson 1962, Steere 1978

*Paludella squarrosa* (Hedw.) Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

**Catoscopiaceae**
*Catoscopium nigritum* (Hedw.) Brid.
Persson 1962, Steere 1978

**Bartramiaceae**
*Bartramia ithyphylla* Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

*Bartramia pomiformis* Hedw.
Steere 1978

*Conostomum tetragonum* (Hedw.) Lindb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Philonotis fontana* (Hedw.) Brid.
Persson 1962

*Philonotis tomentella* Mol.
Johnson et al. 1966, Persson 1962, Steere 1978

*Plagiopus oederiana* (Sw.) Limpr.
Persson 1962, Steere 1978

**Timmiaceae**
*Timmia austriaca* Hedw.
Persson 1962, Steere 1978

*Timmia bavarica* Hessl.
Steere 1978

*Timmia megapolitana* Hedw.
Persson 1962

*Timmia norvegica* Zett.
Persson 1962, Steere 1978

*Timmia norvegica* Zett. var. *excurrens* Bryhn
Steere 1978 as *T. comata*

**Orthotrichaceae**
*Amphidium lapponicum* (Hedw.) Schimp.
Steere 1978

*Orthotrichum anomalum* Hedw.
Steere 1978

*Orthotrichum pellucidum* Lindb.
Steere 1978 as *O. jamesianum*

* *Orthotrichum sordidum* Sull. & Lesq.
Murray 9834, 9892, 9908, det. J. Lewinsky; Steere 1978 as *O. fenestratum* Card. & Ther.
(= *O. sodidum,* Lewinsky in litt. 1983)

*Orthotrichum speciosum* Nees ex Sturm
Johnson et al. 1966 as *O. killiasii,* Persson 1962 as *O. killiasii,* Steere 1978

**Climaciaceae**
*Climacium dendroides* (Hedw.) Web. & Mohr.
Johnson et al. 1966, Persson 1962, Steere 1978

**Neckeraceae**
*Neckera pennata* Hedw. var. *tenera* C. Muell.
Persson 1962, Steere 1978

**Theliaceae**
*Myurella julacea* (Schwaegr.) B.S.G.
Persson 1962, Steere 1978

*Myurella tenerrima* (Brid.) Lindb.
Steere 1978

**Leskeaceae**
*Leptopterigynandrum austro-alpinum* C. Muell.
Steere 1978 as *Garysmithia bifurcata*

*Leskeella nervosa* (Brid.) Loeske
Johnson et al. 1966, Persson 1962, Steere 1978

*Pseudoleskeella catenulata* (Brid. ex Schrad.) Kindb.
Steere 1978

*Pseudoleskeella papillosa* (Lindb.) Kindb.
Steere 1978

*Pseudoleskeella tectorum* (Funck ex Brid.) Kindb. ex Broth.
Persson 1962 as *Leskeella,* Steere 1978

**Thuidiaceae**
*Abietinella abietina* (Hedw.) Fleisch.
Johnson et al. 1966, Persson 1962, Steere 1978

*Claopodium pellucinerve* (Mitt.) Best
Persson 1962, Steere 1978

*Thuidium delicatulum* (Hedw.) B.S.G.
Steere 1978

*Thuidium recognitum* (Hedw.) Lindb.
Steere 1978

**Amblystegiaceae**
*Amblystegium serpens* (Hedw.) B.S.G.
Johnson et al. 1966 as *Amblystegiella,* Persson 1962, Steere and Inoue 1978

*Calliergon cordifolium* (Hedw.) Kindb.
Persson 1962

*Calliergon giganteum* (Schimp.) Kindb.
Johnson et al. 1966, Person 1962, Steere 1978

*Calliergon richardsonii* (Mitt.) Kindb. ex Warnst.
Steere 1978

*Calliergon sarmentosum* (Wahlenb.) Kindb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Calliergon stramineum* (Brid.) Kindb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Campylium stellatum* (Hedw.) C. Jens.
Johnson et al. 1966, Persson 1962, Steere 1978

*Cratoneuron filicinum* (Hedw.) Spruce
Persson 1962, Steere 1978

*Drepanocladus aduncus* (Hedw.) Warnst.
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus badius* (C.J. Hartm.) Roth
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus brevifolius* (Lindb.) Warnst.
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus exannulatus* (B.S.G) Warnst.
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus fluitans* (Hedw.) Warnst.
Johnson et al. 1966, Steere 1978

*Drepanocladus lycopodioides* (Brid.) Warnst.
Steere 1978

*Drepanocladus pseudosarmentosus* (Card. & Ther.) Perss.
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus revolvens* (Sw.) Warnst.
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus revolvens* (Sw.) Warnst. var. *intermedius* Cheney ex Wils.
Persson 1962

*Drepanocladus schulzei* Roth
Johnson et al. 1966, Persson 1962, Steere 1978

*Drepanocladus uncinatus* (Hedw.) Warnst.
Johnson et al. 1966, Persson 1962, Steere 1978

*Hygrohypnum alpestre* (Hedw.) Loeske
Steere 1978

*Hygrohypnum luridum* (Hedw.) Jenn.
Persson 1962, Steere 1978

*Hygrohypnum ochraceum* (Turn. ex Wils.) Loeske
Persson 1962, Steere 1978

*Platydictya jungermannioides* (Brid.) Crum
Johnson et al. 1966, Persson 1962, Steere 1978

*Scorpidium scorpioides* (Hedw.) Limpr.
Johnson et al. 1966, Persson 1962, Steere 1978

*Scorpidium turgescens* (T. Jens.) Loeske
Johnson et al. 1966, Persson 1962, Steere 1978

**Brachytheciaceae**
*Brachythecium albicans* (Hedw.) B.S.G.
Persson 1962, Steere 1978

*Brachythecium salebrosum* (Web. & Mohr.) B.S.G.
Steere 1978

*Brachythecium trachypodium* (Brid.) B.S.G.
Steere 1978

*Brachythecium turgidum* (C.J. Hartm.) Kindb.
Persson 1962, Steere 1978

*Brachythecium velutinum* (Hedw.) B.S.G.
Persson 1962, Steere 1978

*Cirriphyllum cirrosum* (Schwaegr. ex Schultes) Grout
Persson 1962, Steere 1978

*Eurhynchium pulchellum* (Hedw.) Jenn.
Persson 1962, Steere 1978

*Myuroclada maximowiczii* (Borosz. ex Maxim.) Steere & Schof.
Steere 1978

*Tomentypnum nitens* (Hedw.) Loeske
Johnson et al. 1966, Persson 1962, Steere 1978

**Entodontaceae**
*Entodon concinnus* (De Not.) Par.
Persson 1962, Steere 1978

*Orthothecium chryseum* (Schwaegr. ex Schultes) B.S.G.
Persson 1962, Steere 1978

*Orthothecium rufescens* (Brid.) B.S.G.
Steere 1978

**Plagiotheciaceae**

*Plagiothecium denticulatum* (Hedw.) B.S.G.
Steere 1978

*Plagiothecium piliferum* (Sw. ex C.J. Hartm.) B.S.G.
Steere 1978

**Hypnaceae**

*Campylophyllum halleri* (Hedw.) Fleisch.
Steere 1978

*Ctenidium molluscum* (Hedw.) Mitt.
Johnson et al. 1966, Steere 1978

*Herzogiella adscendens* (Lindb.) Iwats. & Schof.
Steere 1978

*Hypnum bambergeri* Schimp.
Johnson et al. 1966, Persson 1962, Steere 1978

*Hypnum callichroum* Funck ex Brid.
Persson 1962, Steere 1978

*Hypnum cupressiforme* Hedw.
Persson 1962, Steere 1978

*Hypnum hamulosum* B.S.G.
Steere 1978

*Hypnum lindbergii* Mitt.
Persson 1962 as *H. arcuatum*, Steere 1978

*Hypnum plicatulum* (Lindb.) Jaeg. & Sauerb.
Johnson et al. 1966, Persson 1962, Steere 1978

*Hypnum pratense* Koch ex Brid.
Steere 1978

*Hypnum procerrimum* Mol.
Persson 1962, Steere 1978

*Hypnum revolutum* (Mitt.) Lindb.
Persson 1962, Steere 1978

*Hypnum subimponens* Lesq.
Persson 1962, Steere 1978

*Hypnum vaucheri* Lesq.
Johnson et al. 1966, Persson 1962, Steere 1978

*Isopterygium pulchellum* (Hedw.) Jaeg. & Sauerb.
Persson 1962, Steere 1978

**Rhytidiaceae**

*Pleurozium schreberi* (Brid.) Mitt.
Johnson et al. 1966

*Rhytidium rugosum* (Hedw.) Kindb.
Johnson et al. 1966, Persson 1962, Steere 1978

**Hylocomiaceae**

*Hylocomium splendens* (Hedw.) B.S.G.
Johnson et al. 1966, Persson 1962, Steere 1978

**Polytrichaceae**

**Oligotrichum falcatum* Steere
Murray 10,276

*Pogonatum dentatum* (Brid.) Brid.
Steere 1978

**Pogonatum urnigerum* (Hedw.) P.-Beauv
Murray 9714, 9749

*Polytrichastrum alpinum* (Hedw.) G.L. Sm.
Steere 1978

*Polytrichastrum longisetum* (Sw. ex Brid.) G.L. Sm.
Persson 1962 as *Polytrichum gracile,* Steere 1978

*Polytrichum commune* Hedw.
Johnson et al. 1966, Persson 1962, Steere 1978

*Polytrichum hyperboreum* R. Br.
Johnson et al. 1966, Persson 1962, Steere 1978

*Polytrichum jensenii* Hag.
Johnson et al. 1966, Persson 1962, Steere 1978

*Polytrichum juniperinum* Hedw.
Johnson et al. 1966, Persson 1962, Steere 1978

*Polytrichum piliferum* Hedw.
Persson 1962, Steere 1978

*Polytrichum strictum* Brid.
Johnson et al. 1966, Persson 1962, Steere 1978

*Psilopilum cavifolium* (Wils.) Hag.
Johnson et al. 1966, Persson 1962, Steere 1978

**Doubtful and Rejected Taxa**

*Andreaea rupestris* Hedw. var. *rupestris*
Johnson et al. 1966, Persson 1962, Steere 1978
This variety may occur, but I have determined the material cited above to be either *A. alpestris* or *A. rupestris* var. *papillosa.*

*Calliergon megalophyllum* Mik.
Johnson et al. 1966, Persson 1962
Karczmarz (1971), who monographed this genus, indicated that *C. megalophyllum* is absent in North America. I have examined the Viereck and Bucknell collection from Ogotoruk Creek, and it seems to fit Karczmarz's concept of a large, aquatic form of *C. richardsonii.*

*Calliergonella cuspidata* (Hedw.) Loeske
Persson 1962
According to Steere (1978) the Persson report from Ogotoruk Creek is probably the only one of this species from arctic Alaska. Steere (1978) has never seen this species in arctic Alaska, and Karczmarz (1971) cites no specimens from there.

*Orthotrichum pylaisii* Brid.
Steere 1978
Lewinsky (in litt. 1983) is not convinced this species occurs in Alaska, and she has re-identified material as *O. sordidum.*

*Psilopilum laevigatum* (Wahlenb.) Lindb.
Johnson et al. 1966
According to D.G. Long (in litt. 1984) the material cited is *P. cavifolium.*

*Racomitrium canescens* (Hedw.) Brid. var. *canescens*
Johnson et al. 1966, Persson 1962, Steere 1978
Frisvoll (1983) found no material in northern Alaska. He has identified Ogotoruk Creek material in the *canescens* group as var. *latifolium, R. ericoides,* and *R. panschii.*

## LICHENS

***Lichinaceae**
**Pyrenopsis pulvinata* (Schaer.) Th. Fr.
Murray 9625, 9826, 9949

***Collemataceae**
**Leptogium saturninum* (Dicks.) Nyl
Murray 9844, 10,298

***Placynthiaceae**
**Placynthium aspratile* (Ach.) Henss.
Murray 9980, 10,428

**Placynthium nigrum* (Huds.) S. Gray
Murray 10,304, 10,431

**Psoroma hypnorum* (Vahl) S. Gray
Murray 9982, 10,013, 10,218

**Pannariaceae**
*Pannaria pezizoides* (G. Web.) Trev.
Johnson et al. 1966

**Peltigeraceae**
*Peltigera aphthosa* (L.) Willd.
Johnson et al. 1966

*Peltigera canina* (L.) Willd.
Johnson et al. 1966

*Peltigera polydactyla* (Neck.) Hoffm.
Johnson et al. 1966

**Peltigera rufescens* (Weis.) Humb.
Murray 9982

*Peltigera scabrosa* Th. Fr.
Johnson et al. 1966, Krog 1962

**Peltigera venosa* (L.) Baumg.
Murray 10,218

*Solorina crocea* (L.) Ach.
Johnson et al. 1966, Krog 1962

*Solorina saccata* (L.) Ach.
Johnson et al. 1966, Krog 1962

**Nephromataceae**

*Nephroma arcticum* (L). Torss.
Johnson et al. 1966

*Nephroma expallidum* (Nyl.) Nyl.
Johnson et al. 1966, Krog 1962

*Nephroma parile* (Ach.) Ach.
Johnson et al. 1966

**Stictaceae**

*Lobaria linita* (Ach.) Rabenh.
Johnson et al. 1966

*Lobaria scrobiculata* (Scop.) DC.
Johnson et al. 1966 as *L. verrucosa*

*Sticta arctica* Degel.
Krog 1962

**Lecideaceae**

*Lecidea aglaea* Somm.
Johnson et al. 1966

*Lecidea flavocaerulescens* Hornem.
Johnson et al. 1966

* *Lecidea melinodes* (Koerb.) Magn.
Murray 9739, 9947

*Lecidea pantherina* (Hoffm.) Th. Fr.
Johnson et al. 1966

*Lecidea pilati* (Hepp) Koerb.
Johnson et al. 1966

* *Lopadium pezizoideum* (Ach.) Koerb.
Murray 9980, 10,287

* *Psora rubiformis* (Ach.) Hook.
Murray 10,447

*Rhizocarpon chioneum* (Norm.) Th. Fr.
Johnson et al. 1966

*Rhizocarpon disporum* (Naeg. ex Hepp) Muell. Arg.
Johnson et al. 1966

*Rhizocarpon geographicum* (L.) DC.
Johnson et al. 1966

*Rhizocarpon inarense* (Vain.) Vain.
Johnson et al. 1966

*Toninia caeruleonigricans* (Lightf.) Th. Fr.
Johnson et al. 1966

**Stereocaulaceae**

*Pilophoron robustus* Th. Fr.
Krog 1962

**Pilophoron vegae* Krog.
Murray 10,039

*Stereocaulon alpinum* Laur.
Krog 1962

*Stereocaulon botryosum* Ach.
Krog 1962

*Stereocaulon glareosum* (Sav.) Magn.
Krog 1962

*Stereocaulon paschale* (L.) Hoffm.
Krog 1962

*Stereocaulon rivulorum* Magn.
Krog 1962

*Stereocaulon apocalypticum* Nyl.
Krog 1962 as *S. wrightii*

**Baeomycetaceae**
*Baeomyces roseus* Pers.
Johnson et al. 1966

**Cladoniaceae**
*Cladina rangiferina* (L.) Harm.
Johnson et al. 1966, Krog 1962 as *Cladonia*

*Cladina stellaris* (Opiz) Brodo
Johnson et al. 1966 as *Cladonia alpestris*

*Cladonia amaurocraea* (Floerke) Schaer.
Johnson et al. 1966, Krog 1962

*Cladonia bellidiflora* (Ach.) Schaer.
Johnson et al. 1966

*Cladonia degenerans* (Floerke) Spreng.
Krog 1962

*Cladonia gracilis* (L.) Willd.
Johnson et al. 1966, Krog 1962

*Cladonia lepidota* Nyl.
Krog 1962

*Cladonia pleurota* (Floerke) Schaer.
Krog 1962 as *C. coccifera* var. *pleurota*

*Cladonia pyxidata* (L.) Hoffm.
Johnson et al. 1966, Krog 1962

*Cladonia uncialis* (L.) Wigg.
Krog 1962

**Umbilicariaceae**
*Umbilicaria hyperborea* (Ach.) Ach.
Krog 1962

*Umbilicaria proboscidea* (L.) Schrad.
Johnson et al. 1966, Krog 1962

**Pertusariaceae**

*Pertusaria coriacea* (Th. Fr.) Th. Fr.
Johnson et al. 1966

*Pertusaria dactylina* (Ach.) Nyl.
Johnson et al. 1966

* *Pertusaria oculata* (Dicks.) Th. Fr.
Murray 10,286

* *Pertusaria subplicans* Nyl.
Murray 9624, 9736, 9788, 10,238

**Acarosporaceae**

*Acarospora glaucocarpa* (Wahlenb. ex Ach.) Koerb.
Johnson et al. 1966

**Lecanoraceae**

* *Haematomma lapponicum* Ras.
Murray 9960

*Lecanora allophana* Roehl.
Johnson et al. 1966

*Lecanora behringii* Nyl.
Johnson et al. 1966

*Lecanora cinerea* (L.) Somm.
Johnson et al. 1966

*Lecanora coilocarpa* (Ach.) Nyl.
Johnson et al. 1966

*Lecanora crenulata* (Dicks.) Nyl.
Johnson et al. 1966

* *Lecanora epibryon* (Ach.) Ach.
Murray 9772

*Lecanora muralis* (Schreb.) Rabenh.
Johnson et al. 1966

*Lecanora pelobotrya* (Wahlenb. ex Ach.) Somm.
Johnson et al. 1966

*Lecanora rupicola* (L.) Zahlbr.
Johnson et al. 1966

*Ochrolechia frigida* (Sw.) Lynge
Johnson et al. 1966

* **Candelariaceae**

* *Candelariella* cf. *terrigena* Ras., sterile
Murray 10,000

**Parmeliaceae**

*Asahinea chrysantha* (Tuck.) W. Culb. & C. Culb.
Johnson et al. 1966, Krog 1962 as *Cetraria*

*Asahinea scholanderi* (Llano) W. Culb. & C. Culb.
Johnson et al. 1966, Krog 1962 as *Cetraria*

*Cetraria andrejevii* Oksn.
Krog 1962

*Cetraria cucullata* (Bell.) Ach.
Johnson et al. 1966, Krog 1962

*Cetraria delisei* (Bory ex Schaer.) Th. Fr.
Johnson et al. 1966

* *Cetraria fastigiata* (Del. ex Nyl. in Norrl.) Karnef.
Murray 9865, 10,051, 10,283

*Cetraria hepatizon* (Ach.) Vain.
Johnson et al. 1966, Krog 1962

*Cetraria islandica* (L.) Ach.
Johnson et al. 1966

* *Cetraria kamczatica* Sav.
Murray 10,005, 10,021

*Cetraria laevigata* Rass.
Krog 1962

* *Cetraria nigricans* (Retz.) Nyl.
Murray 10,180

*Cetraria nigricascens* (Nyl.) Elenk.
Johnson et al. 1966 as *C. sibirica,* Krog 1962 also as *C. sibirica,* Krog 1968 as *C. elenkinii*

*Cetraria nivalis* (L.) Ach.
Johnson et al. 1966, Krog 1962

*Cetraria tilesii* Ach.
Johnson et al. 1966, Krog 1962

*Cetrelia alaskana* (C. Culb. & W. Culb.) W. Culb & C. Culb.
Krog 1962 as *Parmelia cetrarioides*

*Masonhalea richardsonii* (Hook.) Karnef.
Johnson et al. 1966 as *Cetraria*

*Parmelia alpicola* Th. Fr.
Krog 1962

*Parmelia centrifuga* (L.) Ach.
Krog 1962

*Parmelia omphalodes* (L.) Ach.
Johnson et al. 1966, Krog 1962

*Parmelia separata* Th. Fr.
Johnson et al. 1966, Krog 1962

* *Parmelia sulcata* Tayl.
Murray 9919

* *Parmelia stygia* (L.) Ach.
Murray 9878

* *Parmelia taractica* Kremp.
Murray 9885, 9904

* *Parmelia tasmanica* Hook. f. & Tayl.
Murray 9876

**Usneaceae**

*Alectoria nigricans* (Ach.) Nyl.
Krog 1962

*Alectoria ochroleuca* (Hoffm.) Mass.
Johnson et al. 1966, Krog 1962

*Bryoria tenuis* (Dahl) Brodo & D. Hawks.
Johnson et al. 1966 as *Alectoria*

* *Bryoria nitidula* (Th. Fr.) Brodo & D. Hawks.
Murray 9841, 10,250

*Cornicularia aculeata* (Schreb.) Ach.
Krog 1962

*Cornicularia divergens* Ach.
Johnson et al. 1966, Krog 1962

*Dactylina arctica* (Hook.) Nyl.
Johnson et al. 1966, Thomson and Bird 1978

*Dactylina beringica* Bird & Thoms.
Thomson and Bird 1978

*Dactylina ramulosa* (Hook.) Tuck.
Johnson et al. 1966, Krog 1962, Thomson and Bird 1978

*Evernia perfragilis* Llano
Bird 1974, Johnson et al. 1966

*Pseudephebe minuscula* (Nyl. ex Arn.) Brodo & D. Hawks.
Johnson et al. 1966, Krog 1962

*Pseudephebe pubescens* (L.) Choisy
Brodo and Hawksworth 1977, Johnson et al. 1966, Krog 1962

*Siphula ceratites* (Wahlenb.) Th. Fr.
Johnson et al. 1966

*Thamnolia vermicularis* (Sw.) Ach.
Johnson et al. 1966, Krog 1962

**Ramalinaceae**

*Ramalina almquistii* Vain.
Krog 1962

**Buelliaceae**

* *Rinodina roscida* (Somm.) Arn.
Murray 9801

**Physciaceae**

*Physcia caesia* (Hoffm.) Hampe
Johnson et al. 1966, Krog 1962

* *Physcia dubia* (Hoffm.) Lett.
Murray 10,397, 10,399

*Physcia sciastra* (Ach.) Du Rietz
Johnson et al. 1966, Krog 1962

*Physconia muscigena* (Ach.) Poelt
Johnson et al. 1966, Krog 1962 as *Physcia*

**Teloschistaceae**

* *Caloplaca stillicidiorum* (Vahl) Lynge
Murray 9817

* *Fulgensia bracteata* (Hoffm.) Ras.
Murray 9794, 10,393

*Protoblastenia rupestris* (Scop.) J. Stein.
Johnson et al. 1966

*Xanthoria candelaria* (L.) Th. Fr.
Johnson et al. 1966

*Xanthoria elegans* (Link.) Th. Fr.
Johnson et al. 1966 as *Caloplaca*

* *Xanthoria fallax* (Hepp) Arn.
Murray 10,398

**Diploschistaceae**

*Diploschistes scruposus* (Schreb.) Norm.
Johnson et al. 1966

**Verrucariaceae**

*Dermatocarpon miniatum* (L.) Mann.
Johnson et al. 1966, Krog 1962, Krog 1968

* *Polyblastia theleodes* (Somm.) Th. Fr.
Murray 9668, 10,140, 10,305, 10,432, 10,439

* *Polyblastia* sp.
Murray 9769, 10,148, 10,430

* *Staurothele* cf. *succedens* (Rehm) Arnold
Murray 10,437

**Sphaerophoraceae**

*Sphaerophorus fragilis* (L.) Pers.
Johnson et al. 1966, Krog 1962

*Sphaerophorus globosus* (Huds.) Vain.
Johnson et al. 1966, Krog 1962

* **Basidiolichen**

* *Coriscium viride* (Ach.) Vain.
Murray 10,024

**Genus of Uncertain Position**

*Mastodia tesselata* Hook. f. & Harv.
Johnson et al. 1966

**Doubtful and rejected taxa**

*Bryoria nadvornikiana* (Gyeln.) Brodo & D. Hawks.
Krog 1962 as *Alectoria*
According to Krog (1968) this was a misidentification. Brodo and Hawksworth (1977) listed this species as occurring in Alaska only in the Southeast.

*Alectoria jubata* (L.) Ach.
Krog 1962
According to Krog (1968) this species is not considered to occur in Alaska. Brodo and Hawksworth (1977) pointed out that this name has been used for many pendent *Bryoria* species and suggested rejection of the name as a nomen confusum.

*Cetraria ericetorum* Opiz
Johnson et al. 1966 as *C. crispa*
According to Karnefelt (1979) *C. ericetorum* does not occur in Alaska. The material cited by Johnson et al. (1966) is probably either *C. laevigata* or *C. islandica*.

*Evernia esorediosa* (Muell. Arg.) Du Rietz
Johnson et al. 1966, Krog 1962
According to Bird (1974) this material is really *E. perfragilis*.

## NOTES ON SOME TAXONOMICALLY OR FLORISTICALLY INTERESTING TAXA

### Mosses

*Leptopterigynandrum austro-alpinum* C. Muell. (= *Garysmithia bifurcata* Steere, Buck 1980)
This species has a highly disjunct distribution. It is known from a few localities in the Andes (Argentina, Peru and Bolivia), Colorado and Alaska (Steere 1977, Buck 1980), and it has recently been reported from the Mongolian People's Republic and U.S.S.R. (eastern Sayan, Chukchi Peninsula) (Abramova and Abramov 1983). In Alaska it occurs on or at the edge of outcrops (limestone and shale at Ogotoruk Creek, conglomerate at Mile 275 Dalton Highway) in areas of steppe vegetation. Several species are associated with *L. austro-alpinum* at both localities: *Bryum argenteum, Encalypta rhaptocarpa, Phascum cuspidatum, Schistidium tenerum, Tortula ruralis* and the lichen *Parmelia tasmanica* (Murray, unpublished data). Several associates at Ogotoruk Creek also have highly disjunct distributions and frequently occur on dry soil in desert and steppe environments: *Phascum cuspidatum, Pottia* cf. *arizonica* and *Pterygoneurum lamellatum*. *Pterygoneurum lamellatum* is disjunct from Arizona and Utah to Alaska and Northwest Territories (Steere 1978). The *Phascum* and *Pottia* are here reported as new to Alaska, and are, as far as I can discover, new to the Arctic. The varieties they appear to represent are disjunct from Utah (Flowers 1973) to Ogotoruk Creek. This pattern resembles Steere's "Umiat syndrome" (1965), which refers to the large number of mosses disjunct to northern Alaska, at Umiat, with the main portion of their range far to the south in temperate regions.

*Oligotrichum falcatum* Steere
This species has been reported in Alaska only from the type locality in northeastern Alaska (Lake Peters-Lake Schrader). The Ogotoruk Creek collection extends its range to the coast of northwest Alaska. I have also collected this species or seen material from six further localities in arctic and central Alaska (Murray, unpublished data), and it has been found by O.M. Afonina and L.S. Blagodatskikh at numerous localities in Chutkotka and Yakutia, U.S.S.R. (Afonia in litt. 1983).

*Seligeria pusilla* (Hedw.) B.S.G.
This species was one of the ones cited by Steere (1965) in support of his "Umiat Syndrome." My collection at Ogotoruk Creek extends its range westward in Alaska from the Umiat and Chandler River areas.

### Lichens

*Lecidea melinodes* (Koerb.) Magn.
This species was previously reported to occur in Alaska only at Umiat (Thomson 1979).

*Pilophoron vegae* Krog
The only previous Alaska collection is the type specimen from Nunivak Island (Krog 1968). Otherwise, Krog cited only two further collections from the Soviet side of the Bering Strait region. I have also seen unreported collections of this species from British Columbia at the National Museums of Canada.

*Polyblastia* sp.
This apparently undescribed species is not uncommon on limestone in northern Alaska. It is closely related to *P. sommerfeltii* Lynge and *P. theleodes.* Currently under study, it appears to have cephalodia as well as other distinguishing characteristics.

*Staurothele* cf. *succedens* (Rehm) Arnold
My collection clearly represents a taxon new to Alaska. I.M. Brodo and I have tentatively identified it as *S. succedens*, known from Europe.

## APPENDIX B: ADDITIONS TO THE VASCULAR PLANT CHECKLIST FOR CAPE THOMPSON

### Threatened and Endangered Species, and Nomenclatural Changes

D.F. Murray

One hundred and seventy-seven collections were made; these have been processed and are now part of the permanent collection at the Herbarium of the University of Alaska Museum. Most of this additional material was gathered to evaluate morphological variation between populations of taxa from various taxonomically difficult and troublesome groups, particularly the grasses. This brief report updates the checklist to the vascular plants as it appeared in Johnson et al. (1966). Nomenclatural changes are also included, but my treatment is conservative, so Löve and Löve (1975) should also be consulted.

**Taxa New to the Checklist**

*Eriophorum triste* (T. Fr.) Hadac & Love
*Poa abbreviata* ssp. *jordalii* (A.E. Porsild) Hultén
*Carex petricosa* Dewey
*Descurainia sophioides* (Fisch.) Schulz
*Saxifraga nivalis* L.
*Linnaea borealis* L.
*Artemisia arctica* Less. ssp. *arctica*
*Erigeron muirii* A. Gray

**Threatened and endangered species**

*Erigeron muirii* (*E. grandiflorus* ssp. *muirii*) is endemic to northern Alaska. Its type locality is Cape Thompson. It could not be located there during Project Chariot research, so it did not appear on the checklist. The species was rediscovered by David Roseneau, who has supplied us with specimens, photographs and a description of the site. This is a well-marked taxon and one that is quite restricted in distribution. It is a good candidate for threatened status (Murray 1980).

**Nomenclatural changes**

*Agropyron latiglume* (Scribn. & Merr.) Rydb. has been treated as *A. violaceum* (Hornem.) Lange ssp. *violaceum*. Transferred to the genus *Elymus*, this taxon would be named *E. trachycaulus* ssp. *violaceus* (Hornem.) Löve and Löve.

*Calamagrostis neglecta* (Ehrh.) Gaertn., Mey., and Schreb. is an illegitimate name, the correct combination being *C. stricta* (Timm) Koeler. Similarly, *C. neglecta* var. *borealis* of the checklist, treated also as *C. holmii* Lange, is the same as *C. stricta* ssp. *groenlandica* (Schrank) A. Löve (Löve 1970).

*Poa brachyanthera* Hultén has been determined to be the same as *P. pseudoabbreviata* Roshev, which is the older name and must be used (Hultén 1973).

*Elymus mollis* Trin., when transferred to the genus *Leymus*, is *L. mollis* (Trin.) Pilger.

*Kobresia hyperborea* Porsild is now treated as *K. sibirica* Turcz. (Hultén 1967).

*Carex physocarpa* Presl. is *C. saxatilis* ssp. *laxa* (Trautv.) Kalela.

*Luzula nivalis* (Laest.) Beurl. var. *nivalis* is *L. arctica* Blytt (Hultén 1967).

*Luzula nivalis* var. *latifolia* (Kjellm.) Sam. is *L. kjellmaniana* Miyabe and Kudo (Hämet-Ahti and Virrankoski 1971).

*Sagina intermedia* Fenzl is the same as *S. nivalis* (Lindbl.) Fries (Crow 1978).

*Delphinium brachycentrum* of Beringia was treated by Hultén (1973) as *D. chamissonis* Pritz.

*Braya purpurascens* of Johnson et al. (1966) is *B. bartlettiana* Jordal, a Brooks Range species that appears to be an Alaskan variant of *B. aenea* Bunge. This plant, which is otherwise rare in undisturbed tundra, became locally abundant in the disturbances created on the crest of Crowbill Ridge by tracked vehicles. Today there are still many plants found there, but far fewer than appeared soon after the initial disturbance. The same behavior was noted for *B. glabella* R. Br. at Prudhoe Bay on the roadsides.

*Draba caesia* Adams is *D. palanderiana* Kjelm (Porsild 1966).

*Draba hirta* L. is *D. glabella* Pursh (Mulligan 1970).

*Draba lanceolata* Royle is *D. cana* Rydb (Mulligan 1971).

*Draba macrocarpa* Adams is *D. corymbosa* R. Br. ex DC (Mulligan 1974).

*Draba pseudopilosa* of the checklist no longer exists for western Alaska. These specimens have been redetermined and redistributed among the other taxa of *Draba*.

*Smelowskia calycina* (Steph.) C.A. Meyer was given in the checklist as var. *integrifolia* (Seem.) Rolling. In addition, the taxon var. *porsildii* Drury & Rollins is well represented in the Ogotoruk valley.

*Saxifraga radiata* Small of the checklist is *S. exilis* Steph.

*Therofon richardsonii* (Hook.) Kunze is *Boykinia richardsonii* (Hook.) Gray.

*Oxytropis gorodkovii* Yurtsev is the name applied to *O. nigrescens* ssp. *pygmaea* when treated as a species.

*Oxytropis glutinosa* A.E. Porsild is considered an expression of variation in *O. borealis* DC.

*Epilobium palustre* L. from Ogotoruk Creek has been redetermined *E. arcticum* Sam. by Peter Hoch, Missouri Botanical Garden.

*Conioselinum cnidiifolium* (Turcz.) A.E. Porsild can be treated as *Cnidium cnidiifolium* (Tursz.) Schischk.

*Ramischia secunda* (L.) Garcke is *Orthilia secunda* (L.) House (Haber and Cruise 1974).

*Androsace ochotensis* Willd. is being treated as *Douglasia ochotensis* (Willd.) Hult (Hultén 1967).

*Artemisia trifurcata* Steph. ex Spreng. has been placed in synonymy with *A. furcata* Bieb, but Love and Love (1975) have retained the taxon with a chromosome number of $2n = 90$ as *A. trifurcata*. The Cape Thompson-Ogotoruk Creek material is evidently all *A. furcata* (Johnson and Packer 1968).

*Senecio conterminus* Greenm. is a taxon of southern Alberta, and the northern taxon has been named *S. ogotorukensis* Packer (Packer 1972).

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Bibliography: p. 44.
1. Active layer. 2. Alaska. 3. Environmental disturbance. 4. Erosion. 5. Flora. 6. Frost action. 7. Permafrost. 8. Soils. 9. Vegetation. 10. Vegetation recovery. I. Murray, B.M. II. Murray, D.F. III. Johnson, A.W. IV. Linkins, A.E. V. Webber, P.J. VI. United States. Army. Corps of Engineers. VII. Cold Regions Research and Engineering Laboratory, Hanover, N.H. VIII. Series: CRREL Report 85-11.


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